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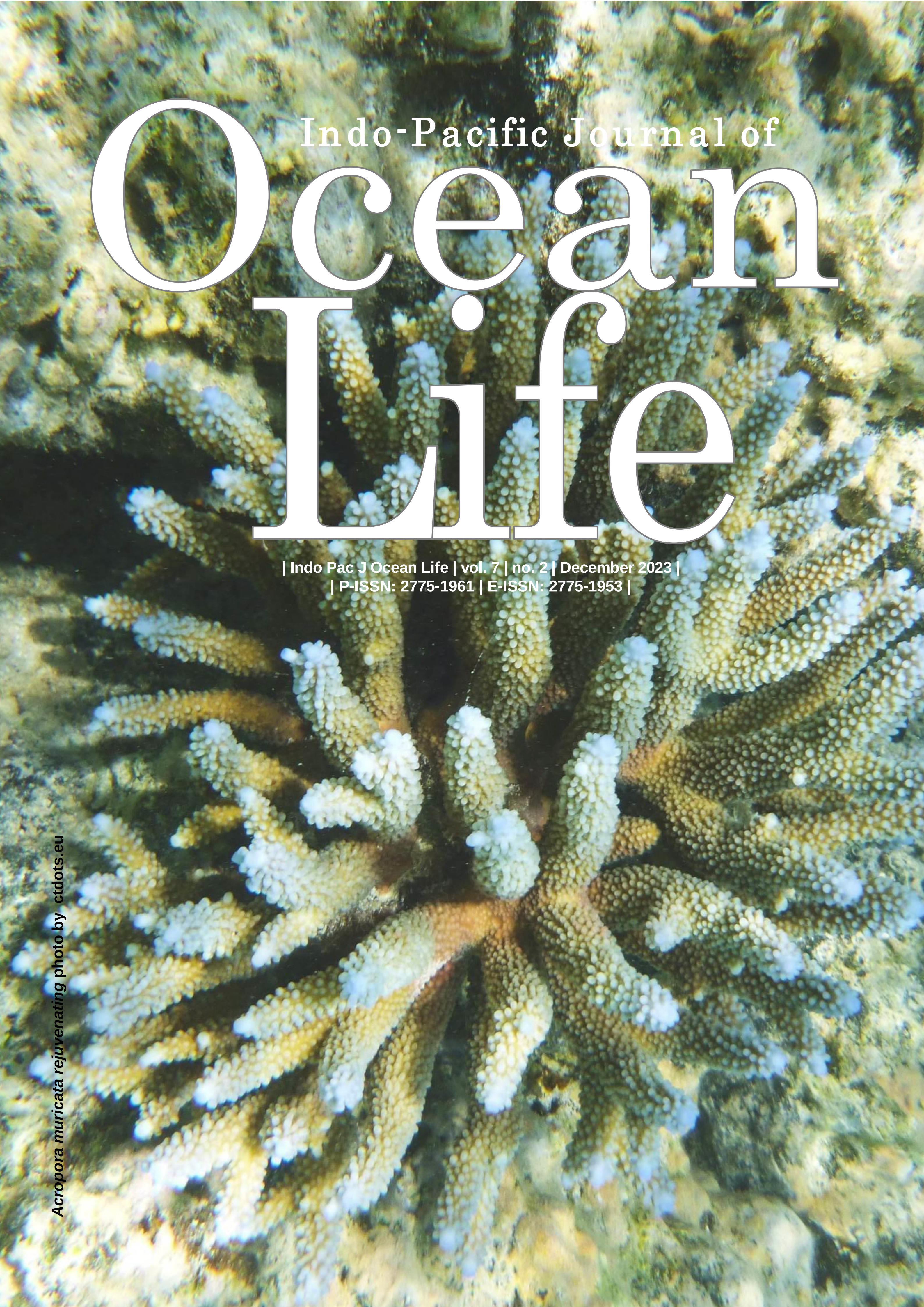

Acropora muricata rejuvenating photo by ctdots.eu

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

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

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

Book:

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

Chapter in the book:

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

Abstract:

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

Proceeding:

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

Thesis, Dissertation:

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

Information from the internet:

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

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Analysis of ecotourism development as a mangrove conservation effort in Pasir Kadilangu and Jembatan Api-Api, Kulon Progo, Yogyakarta, Indonesia

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Abstract. *Astikasari L, Indriyani S, Muryanto BS, Al Madani AR, Muhammad F, Putri A, Hartanti AN, Afifah RN, Zuaini PAK, Rezapratama MS, Negari SIT, Sunarto, Kususmaningrum L, Kurniawati I, Budiharta S, Flores AB, Setyawan AD. 2023. Analysis of ecotourism development as a mangrove conservation effort in Pasir Kadilangu and Jembatan Api-Api, Kulon Progo, Yogyakarta, Indonesia. Indo Pac J Ocean Life 7: 125-132.* Mangrove forests play an important role as a protector of coastal areas from abrasion and tsunamis while providing economic benefits for the surrounding communities. One management option for mangrove forests is through the development of mangrove-based ecotourism that combines the conservation and sustainable utilization of mangrove ecosystems. This study aimed to analyze the mangrove conservation efforts and ecotourism development at Pasir Kadilangu and Jembatan Api-Api, around Bogowonto River, located in Jangkaran Village, Temon Sub-district, Kulon Progo District, Yogyakarta, Indonesia. The study was conducted in November 2022. Primary data was collected through semi-structured observations and interviews using snowball sampling to 100 respondents consisting of 50 respondents at Pasir Kadilangu Beach and 50 respondents at the Jembatan Api-Api, while secondary data were collected through a literature review related to the research being carried out. The results show that efforts to protect and preserve mangrove forests include beach cleaning, greening, and improving the condition of the surrounding environment. The local community utilizes the mangrove forests by selling mangrove products and souvenirs, ticketing, parking, and tour guiding. Most of the community agrees to develop an ecotourism area at Pasir Kadilangu Beach and Jembatan Api-Api Mangrove to protect and preserve mangrove forests while utilizing ecotourism.

Keywords: Conservation, ecosystem, Jembatan Api-Api, mangrove, Pasir Kadilangu Beach

INTRODUCTION

Indonesia has a very large coastal area with a coastline reaching 81,000 km. The coastal areas of Indonesia consist of various supporting ecosystems such as mangrove forest ecosystems, coral reefs, seagrass beds, and wetlands with abundant biodiversity and natural resources such as fish and high-value mining materials (Muchtar et al. 2022). Mangroves are vegetation that lives in coastal areas and estuaries and are affected by tidal currents (Kordi 2012). Mangroves are tolerant to waterlogging conditions with high saline water and soils, with the presence of some prominent species from the genera of *Rhizophora*, *Bruguiera*, *Ceriops*, *Avicennia*, *Xylocarpus*, and *Acrostichum* (Soerianegara and Lemmens 1993). Mangrove ecosystems are divided into three types, namely beach or delta mangrove, river mouth or lagoon mangrove, and island mangrove (Fitriah et al. 2013).

Mangrove forest ecosystems play an immense role in terms of physical, ecological, economic, and socio-cultural functions. Physically, mangrove forests protect coastal areas from abrasion, winds and storms, waves, and tsunamis. The ecological function of mangroves can be seen from their role as the habitat of biodiversity, carbon storage, and neutralizing pollution (Yuswinarto et al. 2019; Sutopo et al. 2022). From the economic aspect, the mangrove ecosystem provides various goods to fulfill human needs, including timber (e.g., firewood, charcoal), non-timber products, and food sources such as fish. Finally, the sociocultural function of mangroves can be seen from their role in ecotourism, education and research area (Kusmana 2015; Harto et al. 2021).

Nowadays, there is an increasing trend in the development of mangrove-based ecotourism, which is promoted as a win-win solution in sustainable mangrove management that delivers benefits not only for conservation and ecological aspects but also for generating income for the surrounding communities. Ecotourism is a form of nature-based tourism that combines aspects of education and interpretation of the natural environment and community culture through environmental management. Ecotourism offers a unified tourism value that integrates the enjoyment of the beauty of nature and efforts to preserve it (Haryanto 2014). Therefore, ecotourism must be developed to minimize the negative impacts of tourism. Such tourism is ideal in Indonesia since the country possesses many natural beauties with aesthetic values (Prastika and Sunarta 2018).

Mangrove forest ecotourism is the development of mangrove tourism objects by paying attention to aspects of environmental suitability and carrying capacity and in its management must avoid risks and negative impacts on the environment (Kusaeri et al. 2015). According to Rianto et al. (2021), mangrove ecotourism can benefit local communities' economic empowerment. In addition, using mangroves as ecotourism areas can provide benefits for mangrove conservation and protection carried out by local communities so that the main functions of the mangrove ecosystem will be maintained. Ecotourism is now very popular in mangrove forests, parallel with the increasing concern for conserving tropical rainforests (Mahmud et al. 2015). Indonesia has the potential to develop mangrove-based ecotourism since the country has 2.5 million hectares of mangrove forest (Rahadian 2019) with unique flora and fauna characteristics (Fahrian et al. 2015). Tourism activities that can be developed in mangrove ecotourism include educational tours and mangrove monitoring, bird watching, fishing, mangrove tree planting, canoeing, and boating. In Sabah, Malaysia, there is potential to develop mangrove ecotourism destinations due to the diversity of forests that support diverse marine life, as well as the stunning landscapes and the unique cultures of local communities (Fazilah et al. 2013). One example of mangrove ecotourism in Indonesia is mangrove ecotourism in Mangunharjo, Tugu District, Semarang City. The management of mangrove ecotourism in the area is carried out by the surrounding community, which is being conducted sustainably. Various benefits are obtained from community-based mangrove ecotourism using their local ecological knowledge and management practices (Ulhaq et al. 2022).

Bogowonto estuary is located on the border of Yogyakarta and Central Java Provinces, Indonesia. In the past, the estuary formed a lagoon with a thick mangrove forest and was protected by sand dunes from the waves of the South Java Sea (Setyawan et al. 2005). Nowadays, most of the mangroves have been converted into agricultural lands, ponds, and settlements. The remaining mangroves are currently left on the banks of the creeks and managed for ecotourism by two operators, namely "Pasir Kadilangu Beach" in the east and "Jembatan Api-Api Mangrove" in the west. The mangrove forest and seaward panoramic of Pasir Kadilangu Beach is a natural tourist attraction at the eastern end of the Bogowonto River. This mangrove forest is managed for environmental protection, shrimp ponds, and nature tourism. On the other hand, the Jembatan Api-Api Mangrove has the attraction of a natural river and mangrove forest. The existence of mangrove-based ecotourism in the Bogowonto estuary has increased the area of mangrove forests by 1,442.55 m². However, the ecotourism activities and the development of facilities and utilities (e.g., photo spots) have also caused disturbances to the surrounding mangroves (e.g., wastes, the opening of mangrove canopy).

Despite the potential of the mangrove forest in Bogowonto estuary for ecotourism, current management is deemed insufficient to meet the good practices in sustainable ecotourism. In particular, there are still limited programs, facilities and utilities to support tourism activities. For example, the tourists are not involved in protecting the mangrove forest, there are no education and awareness programs regarding mangrove conservation, guides, and information centers are not available, and access roads to destinations are very limited. Therefore, it is necessary to identify aspects that support the development of the Bogowonto estuary for ecotourism so that tourism in this area can be marketed internationally (Nugraeni and Setiawan 2017). This research aimed to examine the efforts to conserve mangroves and develop ecotourism in Pasir Kadilangu Beach and Jembatan Api-Api, Kulon Progo, Yogyakarta. We expected the results of this study could be used as a reference for managing the mangrove in the studied area.

MATERIALS AND METHODS

Study area

This research was conducted in two adjacent mangrove forest areas in Pasir Kadilangu Hamlet (named as the Pasir Kadilangu Beach Mangrove Forest) and Pasir Mendit Hamlet (named as the Jembatan Api-Api Mangrove Forest (MJAA), Jangkaran Village, Temon Sub-district, Kulonprogo District, in the westernmost province of Yogyakarta, Indonesia, with coordinates 7˚54˚04‶S 110˚ 02˚ 06‶ E (Figure 1). Jangkaran Village has territorial boundaries with Bogowonto River to the north, the Indian Ocean to the south, Sindutan Village to the east, and Purworejo District to the west and north.

Research procedure

Primary data were collected through observations and semi-structured interviews, while secondary data were collated through an in-depth study of literature related to the research being conducted. The observations aimed to directly see the reality in the research location to support data acquisition. The interviews used a semi-structured method with a questionnaire using a snowball sampling technique in which the head of the management at the research location was the first informant. Snowball sampling uses the main research subject to obtain sample references that meet the research objective's criteria (Lenaini 2021). The other parties interviewed were the community and tourists above 17 years old, which consisted of 50 respondents in the Pasir Kadilangu Beach Mangrove Forest area and 50 in the Jembatan Api-Api Mangrove Forest area.

Data analysis

Data obtained through observation and interviews were analyzed using a qualitative research method with a descriptive approach (Andini et al. 2020). First, the results of community perceptions of ecotourism development were analyzed using the scoring method. The results formulated from data analysis were then described in narratives regarding the people's perceptions on the aspects of protecting mangrove forests, preserving mangrove forest resources, utilizing mangrove forests, and developing mangrove forest ecotourism.

RESULTS AND DISCUSSION

Mangrove forest protection and conservation efforts

Conservation is an effort to manage and maintain essential resources of nature in a balanced and wise manner. According to Syafei (2017), the concept of conservation can be viewed as sustainable management of natural resources considering both ecological and economic perspectives. From an ecological perspective, conservation is the maintenance of natural resources for the future, while from an economic perspective, conservation is the maintenance of natural resources for the present. One form of conservation in sustainable natural management is by applying the concept of ecotourism. Ecotourism is a form of tourism that aims to preserve natural resources that are still natural and provide benefits both ecologically and economically for the local community (Mua and Indahsari 2021). In the context of mangrove forests, the concept of ecotourism can manifest as preserving a mangrove forest so that it can function ecologically, such as protecting coastal areas from wind and waves from abrasion while still generating economic benefits as a tourist spot, conservation and education area. Therefore, it is necessary to carry out conservation efforts to protect mangrove areas so that they function as they should.

Protection and conservation of mangrove forest in Pasir Kadilangu Beach

Based on the results of the observations, the characteristics of the mangrove ecosystem in the Pasir Kadilangu Beach Mangrove Forest are mangrove vegetation located on sloping coastal areas in muddy or inundated by seawater, thus being affected by tidal conditions. The entire local community protects the Pasir Kadilangu Beach Mangrove Forest. Initially, the mangrove forest was preserved only to prevent abrasion. Then, the community saw an opportunity of creating mangrove conservation that could be developed to attract tourists by conducting beach cleaning and reforestation. Cleaning the beach is carried out to remove trash on the beach to increase the attractiveness of tourists and create comfort for visitors (Wulandari et al. 2019).

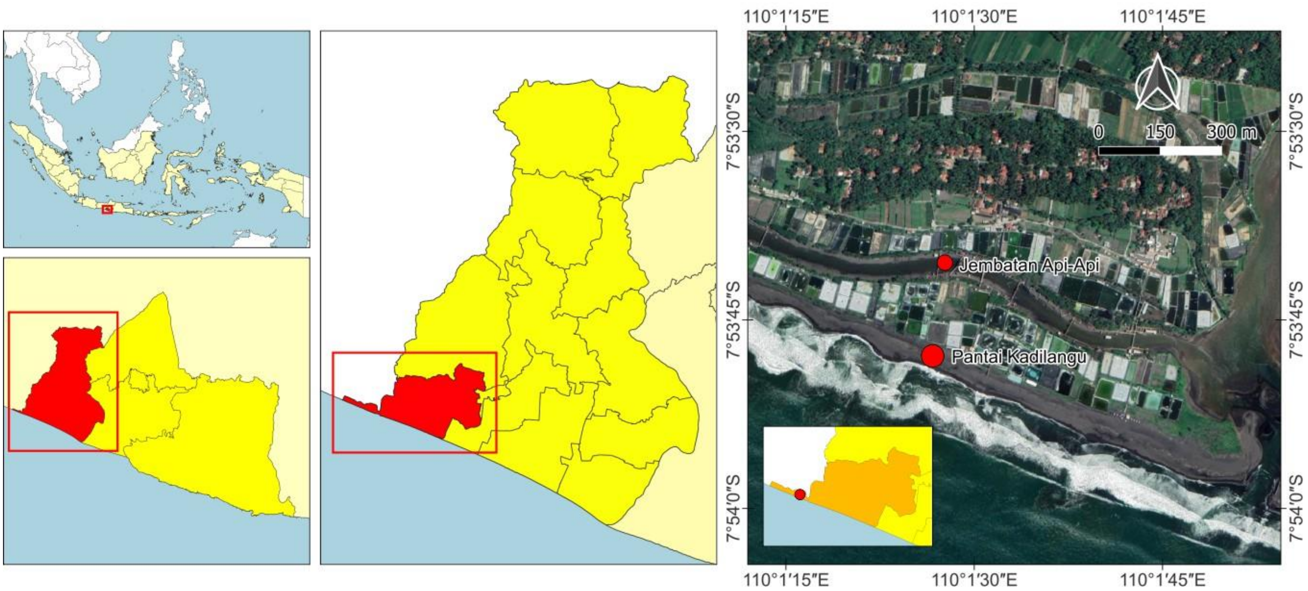

Figure 1. Map the study area of the Pasir Kadilangu Beach Mangrove Forest and the Jembatan Api-Api Mangrove Forest in Jangkaran Village, Temon Sub-district, Kulon Progo District, Yogyakarta Province, Indonesia

The conservation efforts carried out in the Pasir Kadilangu Beach Mangrove Forest are restoration/ rehabilitation by planting mangroves within a particular time and carried out regularly with the help of the surrounding community when there are events. Routine planting is carried out by mangrove managers every six months. Mangrove nurseries were created by planting the seedlings in polybags, and after three months the seedlings are planted with a planting distance of one meter. Monitoring is carried out routinely from the mangrove area and the facilities therein including routinely replacing damaged mangroves. In planting mangroves, the community should pay attention to the health and quality of the mangrove seedlings planted in the mangrove ecotourism area in Kadilangu. The determination of the quality and health of mangrove seedlings can be seen from the condition of the stems, branches, leaves, and roots. In addition, healthy seedlings are not affected by pests (Wibawanti et al. 2018). The community also takes the initiative to maintain the mangrove seedlings with bamboo fences and safety nets to protect mangroves from garbage and household waste from the Bogowonto River hoping that the planted mangrove seedlings will not die and be able to grow well. In the Pasir Kadilangu Beach Mangrove Forest, there are nipa palms (*Nypa fruticans*) which occur on the land where it is not always affected by sea water. The habitat of nipa contains water with very low salinity compared to other zones and mainly grows on the river banks close to the sea.

The local community has a tradition held once a year, namely the Labuhan Samudra ritual or sea alms. This ritual is a form of gratitude to God grace for the surrounding environment. This ritual is began with the Gunungan procession and after the march, the village elders do a prayer, then the Gunungan is thrown into the sea, and the community fights over it. The mountain symbolizes the abundance of fortune that the people of Kadilangu receive.

Protection and conservation of mangrove forest in Jembatan Api-Api

The name of Jembatan Api-Api Mangrove Forest (MJAA) is originated from the dominant presence of *Avicennia* sp. (locally named Api-Api). This species grows near the sea in muddy soil conditions with a slightly sandy substrate. In the area, there is little organic matter and salinity is relatively high therefore the presence of *Avicennia* sp. can increase soil nutrients (Shalsabella et al. 2022). The Jembatan Api-Api Mangrove Forest has the function to provide access and mobility of local fishermen and the area was formerly known as Tambak Ikan, indicated by the distribution of dozens of shrimp ponds that stretch along the coast towards the mangrove tourism route. The area along the river is planted with mangroves which attract the attention of the wider community, especially young people. As more and more residents came to visit, the residents took the initiative to build bridges and go along the river in all directions. After the bridge was built in 2016 to facilitate public access to the pond area, it became famous because it passes through the mangrove area.

Mangrove planting at the Jembatan Api-Api has been carried out since 2005-2006. Then in 2016, a management was formed in which local people in the hamlet were the members. After the formation of the management body, the local community was given capital used to buy mangrove seeds and the mangrove seedlings were planted by each community member under the auspices of the local government. The Jembatan Api-Api mangrove area is managed by individuals of one large family. In the Jembatan Api-Api Mangrove Forest, there has been no production of mangrove seedlings. So to use windbreaks and protect coastal areas, managers and the community buy seeds in the Lamongan area at IDR 5,000 per seedling grown in polybags and then planted along the coastline by workers who have formed labor groups of 22 people per group. Procurement of seeds is carried out to reduce the estimated use of costs required to buy mangrove seeds and is very helpful in preserving mangrove areas (Alfandi et al. 2019).

In the Jembatan Api-Api Mangrove Forest, there are also garbage cleaning activities, especially during the rainy season, aimed to increase public awareness and participation in protecting the coastal and estuary environment to create a clean and sustainable environment (Nurzanah and Indrayani 2021). Currently, the local community in Jembatan Api-Api still really protects the mangroves, indicated by the minimal utilization of mangroves by the local communities.

The community perceived that the protection of the Jembatan Api-Api mangrove forest has an essential role in life, such as resisting sea wind abrasion and erosion. In addition, the mangrove forests can improve the surrounding community's economy. Nonetheless, the good initiatives from the local people that carry out planting and caring for mangroves need to be supported by agencies or institutions.

The mangrove protection and conservation efforts carried out in the Pasir Kadilangu Beach and the Jembatan Api-Api have almost the same approach. These efforts are supported by the adjacent hamlet areas so that the people of the two hamlets can interact and discuss the management and maintain the mangroves in each hamlet. Efforts to protect mangroves by local communities are included in the public environmentalist category, where local people seek to improve environmental conditions directly through their actions and behavior (Laila 2014).

Utilization of mangrove forests

Mangrove forest utilization in Pasir Kadilangu Beach

Most of the mangroves in Pasir Kadilangu Beach Hamlet have been utilized by the community, but not all of them. The use of mangroves was previously limited to environmental services, namely as the protection of coastal areas from the waves to prevent abrasion (Rinjani et al. 2022). However, the potential of well-developed mangrove forests has caused the community to understand the other role of mangrove forests to provide additional economic income. According to Turinso et al. (2018), mangrove forests have significant benefits for improving the economy of coastal communities through ecotourism while conserving biodiversity.

Mangrove forests provide an economic function as a source of livelihood for the people of Pasir Kadilangu Hamlet. Currently, the utilization of mangrove plants by the community includes processing them into pidada syrup which is carried out in groups. The part of the pidada plant (*Sonneratia* sp.) that is processed into syrup is the ripe fruit flesh. The flesh of the pidada fruit is round, green in color, and has a sour taste. The selling price of syrup made from the pidada fruit varies, starting from IDR 5,000 for a 50 mL size. The community also processes mangrove fruit as sweets but in limited quantities. In the mangrove forest, there are also nipa palms used by the community to make sweets and brown sugar. A few people have also used jeruju (*Acanthus ilicifolius*) as medicine in which the leaves is used as an internal medicine and the fruit is eaten to cure ulcers. According to Hakim et al. (2021), jeruju can be used as a medicine for boils, burns, and scabs and as an anti-cancer drug. Beside the flora, the fauna living in mangrove forest areas, such as mussels and crabs, are used by the community for personal consumption, and some are sold. The community uses the surrounding mangrove forest to become shrimp ponds with a selling price of shrimp per kilo from IDR 51,000 to IDR 60,000. Due to the topography of the Pasir Kadilangu Beach Mangrove Forest which is a transitional area between sea and land, most of the residents work as shrimp pond farmers and fishermen.

The community in Kadilangu has also developed the mangrove forest into a tourist area that adds economic income, named the Pasir Kadilangu Beach Mangrove Forest. This activity provides benefits for the community by creating new jobs as employees, selling entrance tickets to tourists, and selling food and drinks. The community is also starting to seriously develop mangrove forests into ecotourism which is also used for conservation and education. There are many stalls which sell knick-knacks and handicrafts made by the residents as souvenirs. There are also boat rentals for visitors to go along the Bogowonto River and see the beauty of the Pasir Kadilangu Beach Mangrove Forest from the boat. Some residents manage the parking, and the incomes are shared equally with the managers. According to Nurdin et al. (2021), the existence of a mangrove ecotourism area can provide benefits for the community by creating new jobs as employees, and selling food and drinks. In addition, the community utilizes the fruit from mangroves to increase economic income regularly but not excessively so that the mangroves are not damaged.

Utilization of mangrove forests in Jembatan Api-Api

The mangrove forest at the Jembatan Api-Api area in Pasir Mendit Hamlet is utilized as the protection of coastal areas from abrasions, tourist attractions, conservation and educational areas, and shrimp pond cultivation. The ecotourism is designated to combine conservation and tourism so that the people of Pasir Mendit Hamlet can increase their income through trading activities, ticketing and parking.

At the Jembatan Api-Api Mangrove Forest, a large and long bridge made of wood and bamboo can be used by visitors to walk around the mangrove tourism spots separated by brackish waters. In addition, there is also a long footbridge used by visitors to enjoy mangrove tour and taking photos. The manager also provides a place to rest and shade for visitors in the form of a gazebo with bamboo seats and a tin roof. However, the effects of the pandemic have caused several facilities to appear poorly maintained, and much of the wood on the bridges is damaged (Figure 2).

The local resident has not optimized the potential uses of *Avicennia* sp. in this area, for example as formalin, firewood, and food ingredients. The fruit of *Avicennia* sp. has a high potential as a raw material for making cakes (Efriyeldi et al. 2019). Thus it becomes a challenge for the community regarding the utilization of *Avicennia* sp.in the mangrove area. The people of Pasir Mendit Hamlet have not yet utilized the mangroves to improve the economy. There needs to be innovation and community expertise to produce mangrove fruit into a processed product that can be sold. Basuki and Putri (2019) state that local community innovation is needed to develope and create added-value products. Previously, there had been training for managers and the community, especially women, in utilizing mangrove plants. However, the utilization of mangrove plants cannot be done haphazardly, and the community does not dare to cut down the mangroves. Mangrove plants are planted for conservation to rehabilitate coastal areas. The Presidential Regulation of the Republic of Indonesia Number 73 of 2012 concerning the National Strategy for Mangrove Ecosystem Management emphasizes that the management of mangrove ecosystems must be sustainable with all efforts to protect, preserve and use them sustainably so that the use of mangroves by the community must consider many factors in order to achieve the sustainability of the function of the mangrove ecosystem.

Community perceptions of ecotourism development

The community perceptions regarding the development of mangrove forest ecotourism in Pasir Kadilangu and Jembatan Api-Api can be viewed from several aspects as shown in Tables 1 and 2. The first aspect is community interest and participation in the development of ecotourism from a physical perspective, such as planning the development of tourist attractions and their objects, providing tour guides, building homestays, creating souvenir shops, and counseling regarding the application of the ecotourism concept itself. Second, the existence of groups or communities that manage ecotourism and the willingness of the community to involve in ecotourism. Third, public opinion regarding the government's role or intervention in developing ecotourism, either entirely or only partially. Fourth, the impact of ecotourism on the local population's economy is good for the whole community or only part of it. Fifth, from the perspective of residents on the impacts of ecotourism, including waste (in village locations and mangrove areas) and damage to mangrove vegetation due to the development of utilities, facilities and attractions. Finally, the community's willingness to realize sustainable ecotourism. The people from the two villages have good understanding regarding ecotourism where they balance economic and conservation aspects.

Figure 2. Tourism utilities and facilities in the Jembatan Api-Api Mangrove Forest, Kulonprogo, Yogyakarta, Indonesia

The result of analysis on community's interest and participation in the development of ecotourism and its facilities, both in the Pasir Kadilangu Beach Mangrove and the Jembatan Api-Api Mangrove showed that almost all of the people support the development of ecotourism. As much as 98% to 100% of the community participates in tourism development planning activities which can be seen from the construction of tourism facilities in the form of bridges in the two villages where the funds used are from non-governmental funding. In addition, community support can also be seen in the presence of traders in tourist areas where most traders agree to have a souvenir shop. For tour guide and homestay activities, some people agree. In contrast, some others follow village policies and decisions as managers of tourist attractions and can be implemented if the tourist conditions are already crowded with visitors.

The community that manages ecotourism in the Pasir Kadilangu Beach Mangrove and the Jembatan Api-Api Mangrove has been around for a long time. Since the beginning of the formation of mangroves in the area, a group of people have actively planted mangroves and started building tourist attractions and facilities until they finally became the managers of these tourist attractions. Other community members are also involved in ecotourism management in the efforts of conservation and protection of mangroves, and the economic sector. However, some members who were not willing to join the management community stated several reasons, including not knowing anything about mangroves, only living in the village because they were following their family members and they have a primary job outside the ecotourism field, so they do not have time and resources.

Table 1. Community perception of ecotourism development in Pasir Kadilangu Beach, Kulon Progo, Yogyakarta, Indonesia

Aspect	Agree	Less agree	Not agree
Willingness to participate in ecotourism development			
Planning activities	50	0	0
Tour guide activities	38	3	9
Souvenir activities	47	1	2
Providing homestay	38	9	3
Counseling about ecotourism	50	0	0
Community perception of ecotourism group			
Group formation	48	1	1
The willingness to join a group	33	7	9
Government intervention in Kadilangu ecotourism			
Partial intervention	41	3	6
Full intervention	8	18	24
Economic benefits of ecotourism			
Economic benefit for the whole community in Kadilangu	44	5	1
Economic benefit only for some participants	26	19	5
Environmental impacts of ecotourism			
Garbage in mangrove forest area	22	4	24
Garbage in village	18	8	24
Damaging the mangrove trees	2	5	43
Damaging the ecotourism facilities	3	5	32
Willingness to develop sustainable mangrove ecotourism	48	2	0

Table 2. Community perception of ecotourism development in Jembatan Api-Api, Kulon Progo, Yogyakarta, Indonesia

Aspect	Agree	Less agree	Not agree
Willingness to participate in ecotourism development			
Planning activities	49	0	1
Tour guide activities	41	7	2
Souvenir activities	47	0	3
Providing homestay	36	6	8
Counseling about ecotourism	50	0	0
Community perception of ecotourism group			
Group formation	50	0	0
The willingness to join a group	38	4	8
Government intervention in Api-Api ecotourism			
Partial intervention	39	2	9
Full intervention	13	8	29
Economic benefits of ecotourism			
Economic benefit for the whole community in Api-Api	47	0	3
Economic benefit only for some participants	30	9	11
Environmental impacts of ecotourism			
Garbage in mangrove forest area	15	6	29
Garbage in village	11	7	32
Damaging the mangrove trees	0	7	43
Damaging the ecotourism facilities	1	6	43
Willingness to develop sustainable mangrove ecotourism	50	0	0

Community's opinion regarding government intervention in the two villages has the same view. Government intervention in ecotourism areas is expected to develop ecotourism areas, especially in the promotion aspect. Most people agree with partial intervention from the government rather than full intervention because they feel this option still prioritizing the village's interests, especially from the economic benefits obtained. In addition, government intervention is also realized through the assistance of mangrove seeds and mangrove improvement and conservation projects. Government intervention can also be in the form of strict regulations enforcement to protect the mangrove areas with their ecological functions (Sabir 2020).

The impact of ecotourism on the community's economy is significant because ecotourism areas can improve the welfare of the local community. As much as 88% (Pasir Kadilangu Beach) and 94% (Jembatan Api-Api) of the community feel that ecotourism provides economic benefits for the residents. The benefits obtained by the community are in the form of profits from trading activities around the tourist sites. The rest of respondents believe that ecotourism can increase their primary income outside the ecotourism sector, namely the ponds. Respondents who earn income from the non-tourism sector believe that when tourism is open, they can open stalls to sell fresh fish along the road, thereby increasing buying and selling power. Ecotourism can provide perceived economic benefits through the existence of economic activities in the tourist areas, such as grocery stalls, food stalls, fish traders, and home industries (Rahim et al. 2022)

The development of ecotourism areas can impact the environment, such as pollution and wastes. In addition, the crowd of visitors can also cause other impacts, such as damage to existing facilities. In both villages, it was found that the presence of tourists did not cause damage to mangroves as a tourist attraction or tourist facilities such as bridges built at these tourist sites. Damage to facilities such as bridges usually occurs when bamboo submerged in the water begins to brittle and break or damage bridges due to rotting wood and high waves reaching the bridge. However, the presence of tourists can produce wastes that contaminate the ecotourism areas. This waste problem has a range of around 20% -30% damage in the form of pollution and garbage in the mangrove areas, so it is still relatively low. Outreach to tourists and waste cleaning programs in ecotourism areas are needed to maintain the cleanliness of the ecotourism environment.

In conclusion, communities in the Pasir Kadilangu Beach Mangrove and Jembatan Api-Api Mangrove fully support sustainable ecotourism. The establishment of ecotourism in the form of mangrove tourism can help improve the population's economy and the ecological function of mangroves as protectors of their villages. The protection of ecotourism areas and the community's role in the surrounding environment is regulated to preserve the resources of the mangrove forest.

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Antimicrobial properties and metabolite profiling of the ethyl acetate fractions of *Sinularia polydactyla* and *Cespitularia simplex* surrounding Mauritius Island

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Abstract. *Jahajeeah D, Bhoyroo V, Ranghoo-Sanmukhiya M. 2023. Antimicrobial properties and metabolite profiling of the ethyl acetate fractions of* Sinularia polydactyla *and* Cespitularia simplex *surrounding Mauritius Island. Indo Pac J Ocean Life 7: 133-142.* Soft corals form an integral part of the reef ecosystem. This study assessed the antibacterial activities of Mauritius Island's soft corals and their different natural compounds having important biological properties. Antimicrobial assays and GCMS-MS analysis were performed using ethyl acetate extracts of *Sinularia polydactyla* and *Cespitularia simplex*. The results for both species indicated significant activity against most clinically pathogenic bacterial strains tested. In addition, *S. polydactyla* and *C. simplex* extracts gave the most potent action spectra yielding the largest inhibition zone diameter, especially against the Gram-positive *Staphylococcus aureus* (8.73 ± 2.87 and 6.00 ± 1.20 mm), respectively. The MIC also confirmed that the Gram-positive *Bacillus subtilis* and *S. aureus* strains were the most susceptible bacteria when exposed to the soft coral extracts, while *Pseudomonas aeruginosa* and *Escherichia coli* were the most resistant Gram-negative strains. The biochemical profile of the extracts showed the presence of terpenoids, steroids, flavonoids, coumarins, and quinones. GCMS-MS analysis also identified 151 compounds in *S. polydactyla* and 91 compounds in *C. simplex*. Several previously published studies have shown the biological activities of different species of *Cespitularia;* however, this is the first study to demonstrate the antibacterial activity and compound profiling of *C. simplex*. Although studies have been carried out on *S. polydactyla* extracts, compounds such as 25-Hydroxycholesterol and spathulenol have not yet been reported. The results from the study suggest that both *S. polydactyla* and *C. simplex* are potential sources of novel antibiotics and possess a myriad of chemical compounds which may lend themselves to bioprospecting.

Keywords: Antibacterial activity, biochemical compounds, GCMS-MS, Mauritius, soft corals

INTRODUCTION

Soft corals have been studied since the nineteenth century as a natural product source (Aratake et al. 2012). Extreme ocean conditions change can lead marine organisms such as soft corals to synthesize various natural biological and chemical products. Soft corals, sessile organisms, have strong chemical defense systems, which produce diverse and complex secondary metabolites (Choudhary et al. 2017; Kusmita et al. 2021;Nurrachma et al. 2021). Over the past 50 years, more than 20,000 natural products have been reported in the marine environment (Blunt et al. 2017). The soft corals' bioactive secondary metabolites, such as terpenoids, cembranoids, and steroids, have exhibited interesting biological properties, including cytotoxic, antifungal, antibacterial, anti-inflammatory, and antifouling activity (Carroll et al. 2020; Tammam et al. 2020). The bioactive compounds found in soft corals have antibacterial properties against a wide range of Gram-positive and Gram-negative bacteria. More than 5,800 secondary metabolites are produced by soft corals (Li et al. 2019), including unique fatty acids, terpenoids, quinones, alkaloids, glycosides, and steroids (Ermolenko et al. 2020). The most studied soft coral species for its bioactive compounds is *Sinularia* sp. This soft coral contains toxins such as diterpenes, sesquiterpenes, norditerpenes, polyhydroxylated steroids, and polyamine compounds, which have been used for drug development (Chen et al. 2012).

The inhibitory activity of these bioactive compounds varies across different bacterial species (Tanod et al. 2018). In addition, the polarity of compounds plays a role in the sensitivity of bacteria. Gram-negative bacteria are generally sensitive to polar antimicrobial compounds, whereas Gram-positive are more sensitive to non-polar antibacterial compounds. The variation in sensitivity of different bacteria is mainly due to the cell wall structure. The outer membrane observed in Gram-negative bacteria is the main reason for the resistance to a wide range of antibiotics (Breijyeh et al. 2020). Moreover, differences in antibacterial activity can be observed within the same soft coral species. A plausible explanation could be the environmental factors that might affect the bioactive compounds present in the organism (Tanod et al. 2018).

Antimicrobial resistance is a worldwide phenomenon, which includes Mauritius Island. Although non-communicable diseases remain the leading cause of death in Mauritius, an increase in deaths due to infectious diseases has also been recorded in recent years (MNAP 2017). The AMR global surveillance report revealed 43.5% and 57.6 % resistance of *Escherichia coli* to 3rd generation cephalosporins and fluoroquinolones, respectively. Those reports also stated 55.8% and 1.9% resistance of *Klebsiella pneumoniae* to 3rd generation cephalosporins and carbapenems, and lastly, 51.5% resistance of *Staphylococcus aureus* to methicillin in Mauritius during one month in 2012 (MNAP 2017). Thus, searching for novel antimicrobial compounds is very important for the well-being of humanity. Furthermore, Mauritius is known to have one of the world's largest Exclusive Economic Zones (EEZ), extending over a surface area of 1.9 million km^2. However, it has not yet been fully exploited. Undoubtedly, the soft marine corals in this area hold potential pharmaceutical drugs and must be inventoried for their antimicrobial and other biological properties.

Previous research showed that *Sinularia* sp. has antibacterial potential (Afifi et al. 2016; Tanod et al. 2018). However, until now, no work has been carried out on the antimicrobial properties and the chemical profiling of *Sinularia polydactyla* and *Cespitularia simplex* around Mauritius Island. *S. polydactyla* and *C. simplex* are the most abundantly present soft corals around Mauritius (Jahajeeah et al. 2021). Compounds, such as spathulenol, 25-hydroxycholesterol, batilol, and others, were identified on GCMS analysis and have been reported from *S. polydactyla* and *C. simplex* for the first time. This study demonstrated the antimicrobial properties of soft corals from Mauritian waters and identified the compounds with myriad biological importance.

MATERIALS AND METHODS

Study area

Samples of the two soft corals, *S. polydactyla* and *C. simplex*, were collected from Albion (57°24'2.99"E: 20°12'42.01"S) and Pereybere (57°35'19.21"E: 19°59'56.67"S) (Figure 1). Both samples were collected at less than 2 m depth during low tides. They were transferred to the lab in zip-lock bags containing seawater, where they were cleaned and frozen at -80°C before a freeze-drying step. The soft corals were previously identified at the molecular level using the COI-COII intergenic spacer marker (Jahajeeah et al. 2021).

Extract preparation

The soft corals were cut into small pieces, weighed, and freeze-dried. The freeze-dried soft corals (70-200g) were exhaustively macerated with ethyl acetate for 48 h. Next, the solution was filtered and evaporated using a rotatory vacuum evaporator set at a temperature of 55°C. The obtained extracts were weighed and stored in sterile corning tubes at 4°C. Finally, the crude extracts were stored for phytochemical and antimicrobial analyses against selected bacteria and GCMS-MS analysis.

Microorganisms and Inoculum preparation

The following microbial strains were obtained from the American Type Culture Collection (ATCC): *Bacillus subtilis* (ATCC 6633), *S. aureus* (ATCC 51153), *E. coli* (ATCC 25922) and *Pseudomonas aeruginosa* (ATCC 27853). All isolates were maintained in nutrient broth at 4°C. The strains were activated by subculture at 37°C for 24 h with fresh Muller Hinton agar (MHA) prior to any antimicrobial tests.

Antibacterial activity

The in vitro antibacterial activity of the soft coral extracts total crude extracts was evaluated using the disc diffusion method using Müeller–Hinton agar with the determination of inhibition zone diameters measured in millimeters (mm) (CLSI 2008). Bacterial cultures were adjusted to a turbidity of 0.5 McFarland (absorbance 0.08–0.1 at 600 nm), and 100 µL of the standardized test strain cultures were plated onto Muller–Hinton agar using an inoculating loop. The plates were dried for approximately 15 min and then used for the sensitivity test. Sterile filter paper discs were saturated with 10 µL of the soft coral extracts and then placed on inoculated Petri dishes. A negative control (ethyl acetate) and a positive control (chloramphenicol) were used for each bacterial strain. All the tests were carried out in triplicate to ensure reliable and accurate results. The plates were inverted and incubated at 37°C for 18 to 24 h. The inhibition zone diameter defines active or inactive soft coral extracts.

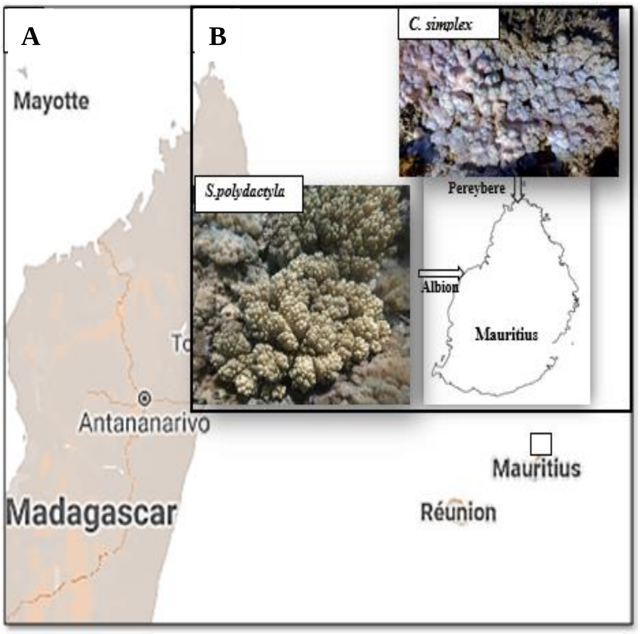

Figure 1. A. Location of Mauritius in the Western Indian Ocean; B. Location of the sample collection sites, Albion and Pereybere around Mauritius Island, with representative images of the soft coral colonies *S. polydactyla* and *C. simplex* present at each sample site

Determination of minimal inhibitory concentration

The soft coral extracts which showed the ability to inhibit the growth of microorganisms were tested for their Minimum Inhibitory Concentration (MIC) using the microdilution technique (Eloff 1998). Test strains were cultured as before and were diluted to a concentration of 1×10^6 CFU/mL and plated on sterile 96 well microplates. All the wells used were filled with 100 µL of Muller-Hinton broth (MHB) except the negative control, which contained only 100 µL of solvent and 100 µL of bacteria. Each sample consisted of 4-5 replicates, with the 5th row containing 10 mg/mL chloramphenicol as the positive control. Apart from the negative control, all the wells were two-fold serially diluted. In addition, 100 µL of inoculum was added to each well, making a total volume of 200 µL. The last column contained only MHB and the inoculum as the control. The microplate was incubated at 37°C for 24 h. P-iodonitrotetrazolium chloride (0.2 mg/mL) was used to indicate microbial growth. Viable bacteria reduced the yellow dye to pink color.

Biochemical analysis

The ethyl acetate aqueous extracts were subjected to several chemical tests to evaluate the presence of secondary metabolites such as alkaloids, flavonoids, saponins, tannins, phenols, anthraquinones, steroids, coumarins, and terpenoids using standard procedures described by Deyab et al. (2016).

GCMS-MS analysis and Compound identification

GCMS carried out the identification and analysis of chemical compounds in the crude extracts. The GC-MS Shimadzu model GC 2010 was used. Exactly 1 µL of the sample was injected in the GC column (SP®-2560; fused silica, 100m×0.25mm×0.2µm, Sigma-Aldrich). Helium was used as the carrier gas at a working constant flow rate of 1 mL/min. The injection volume was 1.0 µL, the injection temperature was 250°C, and the interface temperature was 250°C. The injection took place at an initial oven temperature of 60°C maintained for 5 min, and raised at a rate of 15°C/min till 165°C. That was maintained for 1 min and then raised to 225°C for 20 min at a rate of 2°C/min. Identification of components was achieved based on their retention indices, and the mass spectra were interpreted using the National Institute of Standards and Technology (NIST) database, Wiley library, and GC/MS Forensic Toxicological Database. Each of the compounds identified was verified for their biological importance through published data, and the structure of the biologically important compounds was obtained from NIST.

RESULTS AND DISCUSSION

Antibacterial activity

Both *S. polydactyla* and *C. simplex* ethyl acetate extracts showed significant activity against the bacterial strains. The *S. polydactyla* extract had greater antibacterial activity than the *C. simplex* extract against the pathogenic strains *B. subtilis*, *S. aureus*, *E. coli*, and *P. aeruginosa*. The *S. polydactyla* extract had the most potent action spectra, yielding the largest inhibition zone diameter, especially against the Gram-positive strain *S. aureus* (8.73 ± 2.87 mm). *C. simplex* showed high inhibition against *S. aureus* (6.00 ± 1.20 mm) compared to the other bacterial strains. The positive control chloramphenicol showed an inhibition zone diameter of 13.0 ± 1.41 against *S. aureus*, similar to the inhibitory effect of the *S. polydactyla* extract. Low antibacterial activity (1.80 ± 1.93 mm) and no inhibition were observed for Gram-positive *E. coli* by *S. polydactyla* and *C. simplex*, respectively, when compared to the positive control, which showed the highest inhibition zone diameter of 22.0 ± 2.82 mm (Figure 2).

Minimum Inhibitory Concentration (MIC)

The antibacterial activity of each soft coral extract was further probed to determine its MIC using the micro-dilution assay. The MIC of *C. simplex* for *E. coli* was not performed due to the absence of an inhibition zone using the agar disc diffusion method. The *S. polydactyla* extract had the highest inhibitory effect on the Gram-positive strains *S. aureus* and *B. subtilis*, with a MIC value of 3.26 mg mL^{-1}. *E .coli* and *P. aeruginosa* seemed less sensitive, with a MIC value of 6.51 mg mL^{-1}. Similarly, the ethyl acetate extract of *C. simplex* showed a higher inhibitory effect on *S. aureus* and *B. subtilis*, reporting a MIC value of 1.59 mg mL^{-1}, while *P. aeruginosa* seemed less sensitive, with a MIC value of 6.35 mg mL^{-1} (Table 1). The MIC data confirmed that Gram-positive bacteria were more susceptible than Gram-negative bacteria.

Biochemical analysis

The soft coral extracts were screened for their biochemical components using standard protocols. Both *S. polydactyla* and *C. simplex* showed similar results (Table 2). The presence of terpenoids, steroids, flavonoids, coumarins, and quinones was recorded for both soft corals. However, Alkaloid was only recorded in the *S. polydactyla* extract.

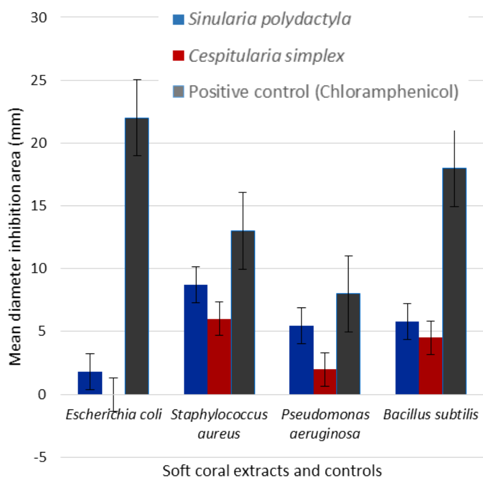

Figure 2. Antimicrobial activity of the two soft coral extracts on different bacteria

GCMS-MS result of soft corals

The current study determined the GCMS-MS spectra of the ethyl acetate extracts of the two soft corals. The compounds identified through the GCMS-MS system were classified into different classes based on their biosynthetic origins: terpenoids, sesquiterpenoids, fatty acid derivatives, sterols, pyrans, alkaloids, ketones, aldehydes, and naphthalene derivatives, with each having a specific retention time. GCMS-MS analysis identified 151 compounds in the *S. polydactyla* ethyl acetate extract and 91 compounds in the *C. simplex* ethyl acetate extract. Sesquiterpenoids (23.84% and 28.60%, respectively) were the class of the most dominant compound found in *S. polydactyla* and *C. simplex*. The compounds produced by the studied soft corals also possess biological activities (Tables 3 and 4).

One hundred and fifty-one compounds were identified in the *S. polydactyla* ethyl acetate extract, and 50 compounds were found to have biological properties based on previous literature. Of the 50 compounds, 21% had antimicrobial properties (antibacterial, antiviral, and antifungal), 18% and 16% had anti-inflammatory and anticancer properties, respectively, and 45% had other biological properties such as antiarthritic, anti-hypercholesterolemic, and anti-oxidative. For the soft coral *C. simplex*, out of the 91 compounds, 17 were found to have biological properties. Of the 17 biologically important compounds, 24% were found to have anti-inflammatory activities, while 17% and 10% had antimicrobial and anticancer properties, respectively. In addition, 49% had other important biological activities such as application in neurodegenerative diseases, treatment of hepatitis, and many more (Figure 3).

Discussion

The current study was conducted to screen the ethyl acetate extracts of Mauritius's most abundant soft corals and test their inhibitory potential on the growth of pathogenic bacterial strains. The soft corals *S. polydactyla* and *C. simplex* were selected as they have 100% coverage at the selected sites. *S. polydactyla* formed large colonies of about 2.5 m at Albion, and *C. simplex* grows extensively on the rocks at Pereybere. The results indicated that the ethyl acetate extracts of *S. polydactyla* and *C. simplex* possess antibacterial activity against most of the tested bacterial strains. Moreover, the data obtained from the Disc diffusion and MIC showed that the Gram-positive strains *B. subtilis* and *S. aureus* were the most susceptible to the soft coral extracts, while *P. aeruginosa* and *E. coli* were the most resistant Gram-negative strains. Soares et al. (2012) reported that Gram-negative bacteria have a unique outer membrane that prevents certain drugs and antibiotics from entering the cell, making them less susceptible. However, the bacteria are not completely protected even with a double membrane. Gram-negative bacteria have hydrophilic ends such as carboxyl, amino acids, and hydroxyl, thus making them more sensitive to polar compounds (Madigan et al. 2000).

Table 1. MIC values of both *S. polydactyla* and *C. simplex* extracts against pathogenic bacteria.

Bacteria	Samples	
	Sinularia polydactyla (mg mL^{-1})	***Cespitularia simplex*** (mg mL^{-1})
Escherichia coli	6.51	-
Staphylococcus aureus	3.26	1.59
Pseudomonas aeruginosa	6.51	6.35
Bacillus subtilis	3.26	1.59

Table 2. Biochemical components in the soft coral extracts.

Biochemical tests	*Sinularia polydactyla*	*Cespitularia simplex*
Alkaloids	+	-
Terpenoids	+	+
Steroids	+	+
Tannins	-	-
Saponins	-	-
Flavonoids	+	+
Phenols	-	-
Coumarins	+	+
Quinones	+	+
Glycosides	-	-

Note: +: Present/detected, -: Absent/Not detected

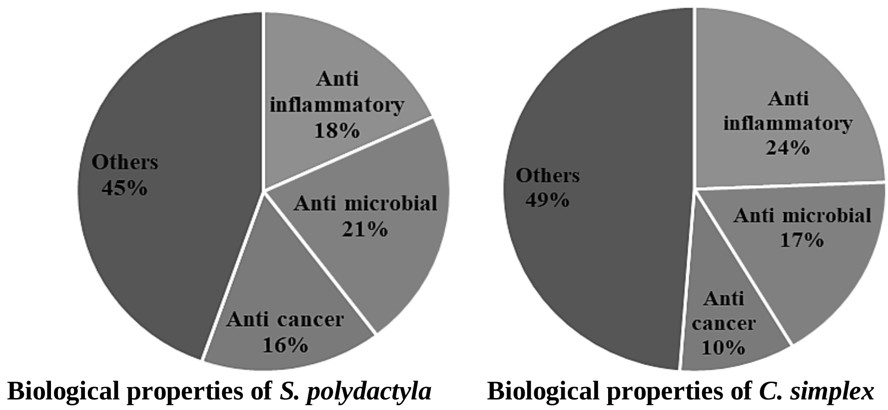

Figure 3. Biological properties of the ethyl acetate extracts of *Sinularia polydactyla* and *Cespitularia simplex*

Table 3. Biological properties of the compounds found in the *Sinularia polydactyla* extract

Biochemical compound	Biological properties	References
Caryophyllene	Anti-inflammatory, antimicrobial, anticancer	Dahham et al. (2015), Hameed et al. (2016)
1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-/ Spathulenol	Antimicrobial, anti-proliferative, anti-inflammatory, immunomodulatory activities	Goud et al. (2002), Ziaei et al. (2011), Tan et al. (2016)
(E)-β-Famesene	Application in neurodegenerative diseases as an alarm pheromone	Russo and Marcu (2017)
1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-	Anti-aging, anti-hyperlipidemia, antimicrobial activities	Mohammad et al. (2016)
7-epi-cis-Sesquisabinene hydrate	Anticancer	Shareef et al. (2016)
Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)-6-methylene-, [S-(R*,S*)]-	Anti-viral	Joshi et al. (2020)
β-Bisabolene	Anti-cancer	Yeo et al. (2016)
Caryophyllene oxide	Anticancer, antifungal, anti-coagulant, anti-inflammatory	Sain et al. (2014), Fidyt et al. (2016)
1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-	Anti-trypanosomal activity, antimicrobial, anti-biofilm, anti-oxidative, anti-parasitic, skin-penetration enhancer, skin-repellent, anti-nociceptive, anti-inflammatory, anticancer	Chan et al. (2016)
12-oxabicyclo[9.1.0]dodeca-3,7-diene, 1,5,5,8-tetramethyl-,[1R-(1R*, 3E, 7E, 11R*)]	Antimalarial activities	Da Silva et al. (2004)
Tetracyclo[6.3.2.0(2,5).0(1,8)]tridecan-9-ol, 4,4-dimethyl-	Antifungal	Narayanasamy et al. (2011)
1,2-15,16-Diepoxyhexadecane	Anti-tumorigenic, anti-inflammatory	Shareef et al. (2016)
1-Naphthalenol, 1,2,3,4,4a,7,8,8a-octahydro-1,6-dimethyl-4-(1-methylethyl)-, [1R-(1α,4β,4aβ,8aβ)]-	Anti-fungal	Chang et al. (2008)
Ar-Turmerone	Antitumor, neuroprotective effect, anti-dermatophytic activity	Mukda et al. (2013), Saga et al. (2020)
alpha-Bisabolol	Anti-inflammatory, anti-tumorigenic, anti-spasmodic, relaxant	Kamatou and Viljoen (2009)
Curlone	Anticancer, anti-inflammatory	Aggarwal et al. (2013)
2-Methyltetracosane	Free radical scavenging activity	Malarvili et al. (2015)
7-Isopropenyl-1,4a-dimethyl-4,4a,5,6,7,8-hexahydro-3H-naphthalen-2-one / α-cyperone	Anti-virulence, anti-genotoxic, antibacterial, anti-depressant, anticancer	Xia et al. (2020)
Jasmolin II	Insecticidal activity	Godin et al. (1965)
n-Butyl laurate	Antimicrobial activity	Kavčič et al. (2013)
Heptadecane	Anti-inflammatory, sex pheromone	Kim et al. (2013)
3,7,11,15-Tetramethyl-2-hexadecen-1-ol / Phytol	Anti-hyperalgesic, anti-inflammatory, antiarthritic, antimicrobial, anticancer	Carvalho et al. (2020), Willie et al. (2021)
2-Pentadecanone, 6,10,14-trimethyl-	Antimicrobial	Olaoye et al. (2017)
Bicyclo[7.2.0]undec-4-ene, 4,11,11-trimethyl-8-methylene-,[1R-(1R*,4Z,9S*)]-	Anti-inflammatory, anti-carcinogenic, antibiotic, antioxidant, and local anesthetic properties	Legault et al. (2013)
n-Hexadecanoic acid	Anti-inflammatory, antioxidant, hypocholesterolemic nematicide, pesticide, anti-androgenic flavor, hemolytic, 5-alpha reductase inhibitor, potent mosquito larvicide	Aparna et al. (2012), Abubakar et al. (2016)
2-Nonadecanone	Anti-inflammatory, anti-depressant, anti-dementia	Lee and Hyun (2018)
Andrographolide	Antidiabetic potential, treatment of hepatitis, anti-inflammatory, antioxidant, antineoplastic properties, antibacterial	Brahmachari (2017); Girish and Pradhan, (2017); Burgos et al. (2020)
Thunbergol	Antibacterial activity	Salem et al. (2014), Mitić et al. (2019)
(-)-Neoclovene-(II), dihydro-	Antimicrobial	Venkata Raman et al. (2012)
n-Nonadecanol-1	Cytotoxic activity	Bernardini et al. (2018)
Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-	Anticancer, Anti-inflammatory	Jiang et al. (2017), Xie et al. (2020)
cis-(Z)-alpha-Bisabolene epoxide	Anti-leishmania activity	Rodríguez-Chaves et al. (2018)
2-Methyltetracosane	Free radical scavenging activity	Malarvili et al. (2015)
Aromadendrene oxide 2	Anti-cancer	Pavithra et al. (2018)
Retinal	Anti-bacterial	Pechère et al. (1999)
Ergost-25-ene-3,6-dione,5,12-dihydroxy(5alpha,12beta)-	Anticancer	Saravanan et al. (2021)
1-Heptatriacotanol	Anti-hypercholesterolemic, antioxidant, anticancer, anti-inflammatory, sex hormone activity	Mohammad et al. (2016); Junwei et al. (2018)
Tetratetracontane	Antibacterial	Gumgumjee and Hajar (2015)
trans-Z-α-Bisabolene epoxide	Anti-inflammatory	Altameme et al. (2016)
25-Hydroxycholesterol	Antiviral effect (on SARS-CoV-2 infection as well)	Zu et al. (2020)
17-Pentatriacontene	Anti-inflammatory, anticancer, antibacterial, antiarthritic	Dineshkumar et al. (2018)
Batilol	Anti-bacterial	Hassan et al. (2016)
6beta-Hydroxymethandienone	Growth hormone	Hooijerink et al. (1999)
1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-	Anti-inflammatory, antiarthritic, antimicrobial, anti-tumorigenic, anti-protozoal, chemopreventive	Jenecius et al. (2012)
Cholesterol	Membrane fluidity	Kohlmeier, (2013)
9,12-Octadecadienoic acid (Z,Z)-	Antibacterial, anti-inflammatory	Rosselli et al. (2007)
Isoaromadendrene epoxide	Antimicrobial, antioxidant, anti-inflammatory	Hameed et al. (2016)
4-Isopropenyl-4,7-dimethyl-1-oxaspiro[2.5]octane	Antimicrobial	Rahman et al. (2014)
Campesterol	Anti-inflammatory, decrease LDL cholesterol	Yuan et al. (2019)
Lupeol	Anticancer, anti-inflammatory, cardioprotective agent	Saleem (2009)

Table 4. Biological properties of the compounds from *C. simplex* extract

Biochemical compound	Biological properties	References
(E)-β-Famesene	Application in neurodegenerative diseases As an alarm pheromone	Russo and Marcu (2017)
β-Elemene	Anticancer, anti-inflammatory	Jiang et al. (2017), Xie et al. (2020)
Andrographolide	Antidiabetic potential, treatment of hepatitis, anti-inflammatory, antioxidant, antineoplastic properties, antibacterial	Brahmachari (2017), Girish and Pradhan (2017); Burgos et al. (2020)
1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1a.alpha.,4a.alpha.,7.beta.,7a.beta.,7b.alpha.)]- / (-)-Spathulenol	Antimicrobial, anti-proliferative, anti-inflammatory, immunomodulatory activities	Goud et al. (2002), Ziaei et al. (2011), Tan et al. (2016)
Viridiflorol	Antimycobacterial, anti-inflammatory, Antioxidant activity	Trevizan et al. (2016)
trans-Z-α-Bisabolene epoxide	Anti-inflammatory effects	Altameme et al. (2016)
Thunbergol	Antibacterial activity	Salem et al. (2014); Mitić et al. (2019)
1-Heptatriacotanol	Anti-hypercholesterolemic effects, antioxidant, anticancer, anti-inflammatory, sex hormone activity	Mohammad et al. (2016) Junwei et al. (2018)
Limonen-6-ol, pivalate	Antioxidant, anti-inflammatory, insect repellent activity	Mohammad et al. (2016)
α-Bulnesene	Paf inhibitor	Tsai et al. (2007)
1-Heneicosanol	Antibacterial activity	Arancibia et al. (2016)
Isoaromadendrene epoxide	Antimicrobial, antioxidant, anti-inflammatory	Hameed et al. (2016)
6-epi-Shyobunol	Anti-inflammatory, antimicrobial, antioxidant	Shareef et al. (2016)
2-Dodecen-1-yl(-)succinic anhydride	Antineoplastic agents, antioxidants, antimicrobial activity	Tanod et al. (2019)
2(3H)-Benzofuranone, 6-ethenylhexahydro-6-methyl-3-methylene-7-(1-methylethenyl)-, [3aS-(3aα,6α,7β,7aβ)]-	Anticancer activity	Alotaibi et al. (2021)
Aromadendrene oxide 2	Anti-cancer	Pavithra et al. (2018)
Bicyclo[4.4.0]dec-2-ene-4-ol, 2-methyl-9-(prop-1-en-3-ol-2-yl)-	Local anesthetic, anti-inflammatory	Shareef et al. (2016)

The ethyl acetate extract from *S. polydactyla*, a polar compound, showed a noticeable inhibition zone against *E. coli* and *P. aeruginosa*. The work by Afifi et al. (2016) on the antimicrobial properties of *S. polydactyla* reported effective inhibitory activity in Gram-positive bacterial isolates (*Bacillus* sp. and *S. aureus*). Rozirwan et al. (2014) also reported antibacterial activity against *E. coli* and *S. aureus* from the semi-polar (EtOAc) and polar (MeOH) fractions of *S. polydactyla.* However, Shaaban et al. (2013) showed that the crude extracts and isolate compounds from *S. polydactyla* showed no antibacterial activities against a wide range of bacterial strains, some of which included *B. subtilis, S. aureus,* and *E. coli.*

Extracts of *C. simplex* showed antibacterial activities against *S. aureus*, *B. subtilis,* and *P. aeruginosa* but no antimicrobial activity against *E. coli* in this study. The ethyl acetate extract of *C. simplex* showed the highest inhibition zone to *S. aureus*. As an antibacterial control, the chloramphenicol inhibition zone diameters for the test bacteria were greater than those of both soft coral extracts. The ethyl acetate extract of *S. polydactyla* confirmed the presence of multiple compounds responsible for various biological activities, with the most prominent ones being the sesquiterpenoids. Khalesi et al. (2008) also reported that more than 60% of the studied soft coral species of *Sinularia* contained terpenoid compounds. Additionally, Yan et al. (2021) showed that the genus *Sinularia* is well-known for producing different complex secondary metabolites, such as sesquiterpenes (10%), diterpenes (46%), norsesquiterpenes (2%), norditerpenes (9%), steroids/steroidal glycosides (22%), and other types (11%) which exhibit a wide range of biological activities including antimicrobial. Caryophyllene, spathulenol, 1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-, 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-, α-Cyperone, n-Butyl laurate, Phytol, 2-Pentadecanone, 6,10,14-trimethyl-, Andrographolide, Thunbergol, (-)-Neoclovene-(II), dihydro-, Retinal, Tetratetracontane, 17-Pentatriacontene, Batilol, 9,12-Octadecadienoic acid (Z,Z)-, Isoaromadendrene epoxide, 4-Isopropenyl-4,7-dimethyl-1-oxaspiro[2.5]octane identified from the GCMS profile of *S. polydactyla* are known for their antimicrobial properties. The presence of these compounds is accountable for the antimicrobial activities of *S. polydactyla* extract against *B. subtilis*, *S. aureus, E. coli,* and *P. aeruginosa*.

Interestingly, β-caryophyllene was previously isolated from soft coral *S. gibberosa,* and *S. nanolobata* were found to possess anticancer properties (Ahmed et al. 2004; Chen et al. 2006). Spathulenol is a rare sesquiterpenoid compound with multiple biological properties found in *Eucalyptus spathulata* and isolated from *S. kavarattiensis* (Goud et al. 2002). Spathulenol has been recorded previously in *S. mayi* (Beechan et al. 1978). However, until now, no reports have been available on the presence of spathulenol in *S. polydactyla*. Finally, Andrographolide, labeled as a prospective pharmaceutical entity, principally isolates from the medicinal plant *Andrographis paniculata*, has been detected in the ethyl acetate extract of *S. polydactyla* from Mauritius. Andrographolide possesses anti-inflammatory, anticancer, antibacterial, and antiviral properties (Brahmachari 2017). Mitić et al. (2019) reported that diterpene alcohol thunbergol might have important antimicrobial properties, and this compound might have contributed to the antimicrobial effect against the tested bacterial isolates.

Thunbergol has been detected in the soft coral eggs of *Lobophytum compactum* and *L. crissum* and is reported to have Antioxidant potential (Sammarco and Coll 1992; Coll et al. 1985). The compound Batilol was previously identified in the soft coral *L. pauciflorum* and has been shown to have antibacterial activity against *B. subtilis*, *Sarcina lutea*, and *Candida albicans* (Hassan et al. 2016). It was also isolate from the Egyptian soft coral *Heteroxenia fuscescens* (Abdelkarem et al. 2021). However, these compounds have never been reported previously in *S. polydactyla*. Isoaromadendrene epoxide has been reported from the extract of *C. stolonifera* but not in any *Sinularia* sp. and *C. simplex*. The compounds 1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-, 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-, α-Cyperone, n-Butyl laurate, Phytol, 2-Pentadecanone, 6,10,14-trimethyl-, (-)-Neoclovene-(II), dihydro-, Retinal, Tetratetracontane, 17-Pentatriacontene, 9,12-Octadecadienoic acid (Z,Z)-, 4-Isopropenyl-4,7-dimethyl-1-oxaspiro[2.5]octane, all possess antimicrobial activity. However, they have not yet been reported in soft corals for their antimicrobial properties.

The *S. polydactyla* ethyl acetate extract possesses other metabolic compounds which are well known for their biological activities. 25-Hydroxycholesterol was detected in the extract, and this molecule has been found to have an antiviral effect on SARS-CoV-2 infection in vitro (Zu et al. 2020). Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)-6-methylene-, [S-(R*,S*)]- has also been reported to have antiviral properties (Joshi et al. 2020). Some of the compounds have been reported to have various properties. For example, 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)- has properties ranging from anti-trypanosomal, antimicrobial, anti-biofilm, Antioxidant, anti-parasitic, skin-penetration enhancer, anti-nociceptive, anti-inflammatory to anticancer (Chan et al. 2016). Besides having anti-inflammatory, Antioxidant, anti-androgenic properties, N-Hexadecanoic acid has been shown to be a potent pesticide and larvicide (Aparna et al. 2012; Abubakar et al. 2016). Moreover, Bicyclo[7.2.0]undec-4-ene, 4,11,11-trimethyl-8-methylene-,[1R-(1R*,4Z,9S*)]- has local anesthetic properties as well as anti-inflammatory, anti-carcinogenic and Antioxidant properties. Huong et al. (2019) isolated six known compounds, namely (1R*,2E,4R*,7E,10S*,11S*,12R*)- 10,18-diacetoxy-dolabella-2,7-dien-6-one,emblide, sarcophine, (3R)-4-[(2R,4S)-4-acetoxy-2-hydoxy-2,6,6- trimethylcyclohexylidene-3-en-2-one, 3β-hydroxypregna-5,16-dien-20-one, and 3 β-hydroxyandrost-5-en-17-one from the methanol extract of *S. digitata*. The steroid constituent, (22R, 23R, 24R)-5α, 8α-epidioxy-22, 23-methylene-24-methylcholest-6-ene-3β-ol, ergosterol peroxide, and 3β-hydroxyandrost-5-ene-17-one, were isolate from the methanol extract of the soft coral Lobophytum crissum from Vietnam (Thao et al. 2015). However, none of these compounds were identified in this study. The extraction and isolation of compounds using different polar and non-polar solvents will extract a wider range of compounds in the soft corals.

The GCMS analysis from the extracts of *C. simplex* identified several compounds which have vital biological activities. The ethyl acetate extract of the latter showed an antimicrobial effect against the test isolates, *B. subtilis*, *S. aureus*, and *P. aeruginosa.* Compounds include Andrographolide, Viridiflorol, (-)-Spathulenol, Thunbergol, 1-Heneicosanol, Isoaromadendrene epoxide, 6-epi-Shyobunol, 2-Dodecen-1-yl(-)succinic anhydride identified from the GCMS analysis might be responsible for the antimicrobial activity in *C. simplex*. 2-Dodecen-1-yl(-)succinic anhydride has been reported in *Sinularia* sp. and *Sarcophyton* sp. showing antineoplastic agents, antioxidants, and antimicrobial activity (Tanod et al. 2019). However, none of these compounds were previously reported in *C. simplex* before. β-Elemene, 2(3H)-Benzofuranone, 6-ethenylhexahydro-6-methyl-3-methylene-7-(1-methylethenyl)-, [3aS-(3aα,6α,7β,7aβ)]-, Aromadendrene oxide 2 identified by GCMS analysis possess anticancer properties. β-Elemene induces antitumor effects against various cell lines such as melanoma cells (Chen et al. 2012), glioblastoma cell lines (Zhu et al. 2014), leukemia cell lines (Yu et al. 2011), breast cancer cell line (Cai et al. 2013) and many more cell lines. 2(3H)-Benzofuranone, 6-ethenylhexahydro-6-methyl-3-methylene-7-(1-methylethenyl)-, [3aS-(3aα,6α, 7β, 7aβ)]- also known as dehydrosaussurea lactone has an inhibitory effect against breast cancer cell growth (Peng et al. 2017). Aromadendrene oxide 2 induces apoptosis in skin epidermoid cancer cells (Pavithra et al. 2018). (E)-β-Famesene has been studied for its application in neurodegenerative diseases as an alarm pheromone (Russo and Marcu 2017). Limonen-6-ol, pivalate has been reported to have antioxidant, anti-inflammatory, and insect-repellent activity (Mohammad et al. 2016). Bicyclo [4.4.0]dec-2-ene-4-ol, 2-methyl-9-(prop-1-en-3-ol-2-yl)- has local anesthetic and anti-inflammatory properties (Shareef et al. 2016). From these data, we can confirm that *C. simplex* possesses myriad compounds with pharmaceutical properties.

In conclusion, the Mauritian soft corals *S. polydactyla* and *C. simplex* have potential medical value, particularly high antibacterial properties against various pathogenic bacteria. The qualitative biochemical test showed the presence of various bioactive compounds such as terpenoids, steroids, and coumarins which can be responsible for the antibacterial activities. Moreover, the

GCMS-MS analysis identified important compounds which possess vital biological properties. Therefore, identifying biologically important compounds from the soft corals from Mauritius may be harnessed for future pharmaceutical exploration. Future studies should include testing different soft coral species' solvent extracts, such as methanol, and a wider range of bacteria. Furthermore, with the emergence of various deadly diseases and viruses, anticancer and antiviral properties can also be tested to study the effectiveness of these crude extracts.

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The application of the blue economy concept for traditional fisheries management in a conflict zone

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Abstract. *Bidayani E, Reniati, Priyambada A. 2023. The application of the blue economy concept for traditional fisheries management in a conflict zone. Indo Pac J Ocean Life 7: 143-147.* The blue economy refers to an environmentally friendly management concept to ensure the sustainability of fish resources, considered an effective method in minimizing conflicts of interest in coastal areas. This study focused on one of the conflict zones in the Province of the Bangka Belitung Islands, located on the coast of Kebintik Village and Batu Belubang Village, Pangkalan Baru Sub-district, Central Bangka Province, Indonesia. This study aims to: (i) Analyse the implementation of the blue economy principles and (ii) Analyse the traditional capture fisheries management in conflict zones for sustainable fish resources. The research was conducted from June to July 2022. The population in this study includes traditional fishermen who have operated for more than one year in coastal areas, as many as 30 people and 30 people affected by the community's conflict. The research method of this study was a survey, while the data collection was conducted using census techniques and focus group discussions, generating both primary and secondary data. Primary data collection was conducted using a questionnaire, observation, and documentation. Meanwhile, secondary data collection was conducted through a literature study. The data analysis method used in this study is the descriptive method. The conclusions of this study are: (i) Implementation of blue economy principles, including resource efficiency, zero waste, social care, production cycle systems, investment, innovation, and adaptation, ranging from 86% - 100% or high category; and (ii) Traditional capture-fisheries management in conflict zones for sustainable fish resources which is considered as a compromise.

Keywords: Bangka, blue economy, conflict, fishermen, management

INTRODUCTION

In Indonesia, capture fisheries are dominated by small-scale fisheries. More than 78% of fishing fleets are under 10 Gross Tonnage (GT), and around 95% use outboard motorboats and non-motorized boats with simple fishing gear (Rahim et al. 2019; Nababan 2020; Patawari et al. 2022). The small-scale fisheries' role is very dominant, with more than 80% of capture fisheries production in Indonesia derived from small-scale fisheries' contribution (Adhuri et al. 2016).

However, the sustainability of small-scale fisheries-based livelihoods is vulnerable to shocks and sudden changes. They face challenges ranging from various factors and processes, such as weak governance, insecure tenure, weak access to tenure and average incomes, and political and market powerlessness (Barr et al. 2019). In addition, small-scale fisheries are also faced with various risks from fishing activities and economic risks stemming from natural disasters such as climate change (Sari and Muslimah 2020).

Generally, fishermen have limited resources, but on the other hand, fishermen also want to increase their fishing effort. Therefore, fishermen must consider the production factors in efficiently running their capture fisheries business (Sukiyono and Romdhon 2016). Increasing fishermen's catch skills depends on the production inputs used. Further, information regarding the effect of production inputs is required, which results in optimal fishing efforts by applying effective and efficient production inputs to increase catches and fishermen's income (Alhuda et al. 2016). However, the effectiveness and efficiency of fishing gear and the use of other production factors are still not optimal. This situation affects the income and level of welfare for fishermen. The current suboptimal production in the fisheries sector is mainly due to the low productivity of fishermen (Yonvitner et al. 2020).

In addressing the situation mentioned above, the present authors propose the concept of the "Blue economy," which is an environmentally friendly management concept to ensure the sustainability of fish resources. This concept is an economic development that relies on marine resources associated with sustainable resource management and focuses on three perspectives: economic, ecological, and social factors. The blue economy emphasizes innovation more to meet fishermen's needs through increasing added value at every stage, thus requiring innovation skills (Bidayani and Priyambada 2022). However, economic activities in the coastal area of Batu Belubang Village, Pangkalan Baru Sub-district, and Central Bangka District can cause conflict due to unconventional tin mining activities and limited capture fisheries in the village area (Bidayani 2022). Through this study result, it is hoped that conflicts in coastal areas can be managed by applying a blue economy concept approach and creating justice for all regional stakeholders.

According to Saefullah (2012), the emergence of conflict is motivated by a mismatch of goals. Moreover, according to Ni'mah (2016), the characteristics of conflict include antagonistic interactions, differences in conflicting and disturbing goals, and the presence or absence of open resistance. In addition, Fisher (2001) pointed out that conflict resolution becomes an attempt to deal with the causes of conflict by establishing new and long-lasting relationships among hostile groups. Further, Wirawan (2010) asserted that conflict resolution is achieved in two ways: self-regulation by the conflicting party and the intervention of a third party. Furthermore, compromise can also be used to manage conflicts. According to Kreitner and Kinichi (2014), conflict management styles include integrating (problem-solving), obliging (smoothing), dominating (forcing), avoiding, and compromising. Furthermore, managing conflict is motivated by many factors, such as the economy and social strata in the organization, emphasizing that every involved individual can understand the conflict and know how to manage it (Mulyani et al. 2020). Elaborating, effective communication is required to encourage the creation of appropriate conflict resolution (Wianti et al. 2020).

MATERIALS AND METHODS

The research was conducted in Kebintik Village and Batu Belubang Village, Pangkalan Baru sub-sub-district, Central Bangka Province, Indonesia from June to July 2022. The location selection technique was considered intentional (purposive sampling), including the conflict zones for unconventional mining and capture fisheries. The method used in this study was a survey method, in which the main source of data and information is obtained from respondents as research samples using a questionnaire as a data collection instrument. The sampling method was purposive, including 30 traditional fishermen in Kebintik Village and 30 people (non-fishermen) affected by the conflict-affected in the Batu Belubang Village community.

Data collection methods in this study were primary data and secondary data. Primary data collection was conducted through interviews to analyze the implementation of the blue economy principle and Focus Group Discussion (FGD) to analyze traditional capture fisheries management. FGD empowerment persons from the Regional Development Planning, Research and Development Agency (BAPPEDA) of Bangka Belitung Islands Province and the Head of Batu Belubang Village. Meanwhile, secondary data collection was conducted through a literature study. The data analysis method used in this study is the descriptive method. Therefore, the data analysis method used is the descriptive method, which describes the situation that occurs systematically and factually to describe and solve research problems. The blue economy principles (or concept) include resource efficiency, carelessness, social care, production cycle systems, investment, innovation, and adaptation. Data analysis applies the percentage formula (Azwardi 2018), which is as follows:

$P = f/N \times 100$
Where:
P: percentage number;
f: frequency sought by the percentage
N: number of frequencies used as ata

Each indicator is measured through statements using three scores: 1 disagree, 2 doubtful, and 3 agree. The formula for making class intervals (Prabawa 2020) is as follows:

NR = NST-NSR
PI = NR : JIK
Where:
NR : value range
NST : highest score score
NSR : the lowest score
PI : interval length
JIK : number of class intervals

The percentage value of the interval in this study is:
Percentage interval criteria
77.9-100% high
55.6-77.8% enough
33.3-55.5% low

RESULTS AND DISCUSSION

The blue economy principles (or concept) include resource efficiency, zero waste, social care, production cycle systems, investment, innovation, and adaptation. The fishing effort of traditional fishermen in the productive seasons, which are in March, May, June, August, and October, indicates that all respondents (100%) are efficient. Meanwhile, in the bad season (besides the peak/productive seasons), 57% of fishermen break even (R/C = 1), 33% (R/C <1) are inefficient, and 10% (R/C > 1) are efficient. This study's results align with the research of Nainggolan et al. (2021), reporting that the income of traditional fishermen in the productive fishing season is around IDR 65,000/day or IDR 980,000/month. Meanwhile, in the bad season, the income of traditional fishermen is IDR 13,000/day or IDR 205,000/month. The implementation of the principle of resource efficiency is presented in Figure 1.

Referring to the study of the zero waste principle, the catch of traditional fishermen can provide economic benefits wholly. As many as 86,67% of fishermen stated that their catch provided economic benefits (sellable), while 13,33% of fishermen stated that the fish not sold was typically consumed by themselves. Moreover, fishermen can process fresh fish into various processed products to increase income. This finding/ statement is reinforced by Nainggolan et al. (2021), denoting that the government can provide fish processing training to fishermen to increase their added value.

Social care in this study (as the third principle under the Blue Economy concept) is defined as a traditional capture fisheries business that can create another informal job. The results reported that their family members assisted 16.7% of fishermen, and 83.3% of fishermen ran a business assisted by friends, with the majority assisting just one person. According to Sujarno (2008), the need for a workforce must be adjusted to the capacity of the operated ship to manage efficient fishing costs. The implementation of zero waste and social care principles is presented in Figure 2.

The production cycle system indicates that the traditional capture in fisheries business continuously runs while conflict exists. Bidayani and Reniati (2021) reported that as many as 90% of fishermen can still conduct fishing activities by changing locations, particularly in conflict zones. The fishermen experience difficulty in getting fish, which encourages them to change the catching location.

The willingness attempts of traditional fishermen to invest in business include innovating to increase productivity and adapting in conflict zones. All fishermen (100%) are willing to invest in the business by increasing the number of fishing gear and adding bait variations to increase productivity as a form of adaptation in conflict zones. According to Nainggolan et al. (2021), the government can provide financial support for procuring fishing facilities and infrastructure. The implementation of the blue economy concept, production, investment, innovation, and adaptation cycle system is presented in Figure 3.

In this study, the analysis of traditional capture fisheries management in conflict zones for sustainable fish resources was based on the blue economy concept. This concept includes village government policies related to activities in coastal areas, approaches used in conflicts of interest, efforts to create peace in the community, appropriate empowerment programs to help fishermen, and stakeholder expectations for sustainable fish resources.

The policy implemented by the Batu Belubang Village Government related to activities in coastal areas, especially for fishermen, includes: increasing the capacity of Human Resources, providing facilities and infrastructure (cold storage, fishing gear assistance, counseling, good fishing training, additional facilities such as Fish Auction Places, and assisting in pier extension. Meanwhile, policies for tin mining include: setting up mining zones, encouraging licensed tin mining, prohibiting mining in fishing areas, and controlling illegal tin mining activities. According to Nainggolan et al. (2021), the strategy to increase fishermen's income is considered an aggressive strategy, including forming fishing groups and using modern fishing gear.

In this study, deliberation is the approach used if there is a conflict of interest in the coastal area. Efforts to create peace in the community are by setting operational areas, not interfering between tin miners and fishermen, and demanding compensation from mining activities in fishing areas. According to Bidayani and Hartoko (2019), compromise can be used to manage conflict. Appropriate empowerment programs to assist fishermen include training and mentoring fishermen and fish processors and facilitating other fishermen's needs. Apart from the fishermen dimension, stakeholders expect that fish resources are sustainable, including setting up marine space utilization zones, using environmentally friendly fishing gear, and maintaining the cleanliness of the marine surrounding. According to Nainggolan et al. (2021), the government should routinely conduct outreach and training for fishermen to process fish and preserve sustainable marine and coastal resources.

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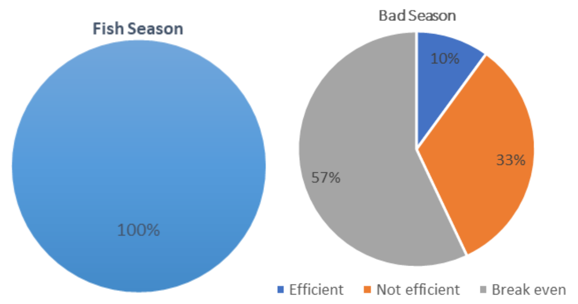

Figure 1. The implementation of the principle of resource efficiency

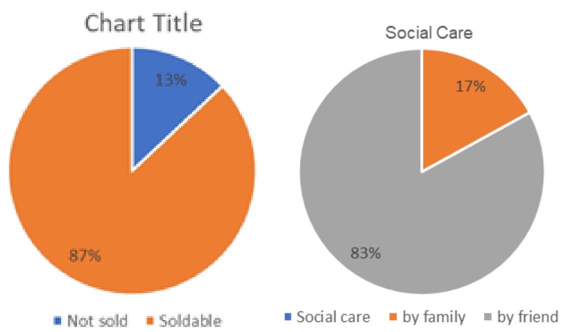

Figure 2. Implementation of zero waste and social care principles

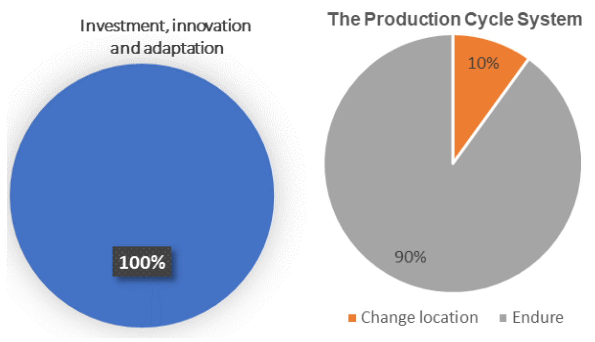

Figure 3. Investment, innovation, and adaptation

Discussion

Conflicts in coastal areas between traditional fishermen and unconventional tin miners have put pressure on traditional capture fisheries. Therefore, the blue economy concept is expected to provide a policy direction for developing sustainable traditional capture fisheries. Based on the result of this study, the conclusions of this study are: 1) Implementation of blue economy principles includes resource efficiency, zero waste, social care, production cycle systems, investment, innovation, and adaptation ranging from 86% - 100% or high category; and 2) Traditional capture fisheries management in conflict zones for sustainable fish resources is a compromise.

Based on the finding of this study, utilization of coastal areas at the same time and space tends to cause trade-offs for the users. Furthermore, as users, small fishermen are vulnerable due to experiencing the most pressure from the impact of the trade-off (Mardyani and Lindawati 2021). This study also revealed that the allocation of coastal and marine space on Bangka Island, which is dominated by mining activities, has caused various problems, especially for capture fisheries activities (Nurtjahya and Agustina 2015; Manik 2018; Pratama 2018; Bidayani and Hartoko 2019; Bidayani and Kurniawan 2020; Bidayani et al. 2020; Ramadona et al. 2020; Bidayani and Reniati 2021; Bidayani and Priyambada 2022). In addition, the existence of a marine Mining Business Permit (IUP) adjacent to the location of the fishing area (DPI) causes conflicts with local fishermen (Ibrahim et al. 2018; Sulista et al. 2019). Therefore, the causal factors indicate conflicts that exist due to environmental damage are the practice of one party that harms fishermen included in the type of environmental conflict (Satria 2015). In addition, conflicts of interest between fishermen and miners present a major problem for the sustainability of the two sectors: capture fisheries and tin mining (Ramadona et al. 2020).

In sum, implementing the blue economy principles, including resource efficiency, zero waste, social care, production cycle systems, investment, innovation, and adaptation, is expected to be a solution for managing traditional-scale capture fisheries resources. In addition, this study suggests setting up marine space utilization zones, using environmentally friendly fishing gear, and empowering fishermen programs to increase income.

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Estimation of aboveground carbon stock based on mangrove zones in Ijo River Estuary, Ayah Village, Kebumen, Indonesia

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Abstract. *Ningtyas SRA, Mu'ali AYF, Putri DNAR, Silaningtyas NW, Tsabita FA, Aprianto MK, Sari SP, Fauziyyah MD, Nugraheni RS, Juniati SD, Isa MN, Nofitasari H, Sutarno, Sugiyarto, Indrawan M, Yap CK, Budiharta S, Setyawan AD. 2023. Estimation of aboveground carbon stock based on mangrove zones in Ijo River Estuary, Ayah Village, Kebumen, Indonesia. Indo Pac J Ocean Life 7: 148-155.* The increasing concentration of greenhouse gases, including carbon dioxide in the atmosphere is the driver of global warming which triggers climate change. One strategy to mitigate climate change is reducing carbon emissions and increasing the carbon stock. Mangrove forest is recognized as the largest carbon sink on the Earth, therefore, the conservation and restoration of mangrove forest are increasingly promoted as an effective way to tackle climate change. While many studies assess the carbon stock of mangrove forests, a context-specific assessment is needed to enrich the existing studies in this field. This study aimed to investigate the aboveground carbon stored in vegetation occurring in three mangrove zones (i.e., seaward, middle and landward zones) in Ijo River Estuary, Ayah Village, Kebumen, Central Java, Indonesia. Purposive sampling on each mangrove zone was conducted with vegetation data at tree and pole stages collected using nested plot methods. Aboveground biomass was calculated using an allometric equation while carbon stock was estimated using the method of the National Standardization Agency. In total, there were 11 mangrove species in the observation plots, consisting of seven true mangrove species and four mangrove associates. The seaward zone had five species and an amount of aboveground biomass (29324.07 MgB/ha), while the middle zone consisted of five species and had biomass of 52776.62 MgB/ha, and the landward zone was composed of five species and had biomass of 6428.74 MgB/ha. The carbon stock in the seaward, middle and landward zones were 43.06, 197.42 and 186.00 MgC/ha, respectively. In total, the Ayah Mangrove Forest contained aboveground biomass of 88529.43 MgB/ha, equal to 1143.31 MgC/ha carbon stock. The findings of this study reiterate the importance of conserving mangrove forests as an effective way to reduce carbon emissions which are the major cause of global warming.

Keywords: Carbon-stock, climate change, mitigation, Kebumen, zonation mangrove

INTRODUCTION

Climate change is caused mainly by anthropogenic activities, either directly or indirectly, leading to variabilities in climate and atmospheric composition in a relatively short period compared to historical changes during the Earth's epoch. Climate change has negatively impacted various life systems on the Earth, making it one of the global most important issues in recent decades (Gerard et al. 2020). One of the drivers of climate change is global warming (DITJEN PPI MENKLHK 2017). Global warming can be defined as the increase of the average temperatures at atmospheric, ocean, and terrestrial levels. It happens because the sun's radiation is not reflected in the atmosphere. Instead, it is trapped in the Earth due to the high concentration of greenhouse gases, such as methane and carbon dioxide. Therefore it is often called the greenhouse effect. The drastic increase in the concentration of greenhouse gases will lead to hotter temperatures on the Earth which can drive various climate phenomena such as storms, extreme rain, and prolonged drought, which eventually trigger disasters such as floods, landslides, forest fires, drought, water and food crises, etcetera (Triana 2018). Among the greenhouse gases, carbon dioxide is considered the most significant contributor to the warmer climate due to its greatest concentration in the atmosphere caused by the increased emission in the Anthropocene era (Manabe 2019). While there are several strategies to reduce carbon dioxide emissions, one strategy that has low cost is through carbon sequestration stored in plant biomass.

Among various vegetation types, mangroves are the most significant carbon sink, which has a high potential contribution to climate change mitigation.

Mangroves grow in areas between terrestrial and coastal zones (Mulyana et al. 2021). This vegetation type is affected by intertidal sea waves, high saline water, and soil. Therefore mangroves are commonly found on coastlines and estuaries. Mangrove forest is a transitional ecosystem between terrestrial and coastal areas and only occurs in tropical and subtropical regions. Prominent species usually indicate this ecosystem with specific morphological characteristics, such as thick leaves and knee roots (Sarker et al. 2021).

The mangrove ecosystem plays essential roles in the physical, ecological, and socio-economic aspects (Pattimahu et al. 2020). From a physical perspective, the presence of mangrove forests serves as protectors from waves, winds and storms, abrasion, and tsunamis. In terms of ecological aspects, it acts as the habitat of high diversity of flora and fauna and neutralizes coastal pollution. From a socio-economic view, the mangrove ecosystem provides sources of livelihood for the surrounding communities from various goods (e.g., timber, firewood, fish) and is developed for ecotourism. With increasing concerns about climate change, many recent studies revealed that the mangrove ecosystem sequesters and stores a significant amount of carbon in the vegetation and the soils effectively compared to other ecosystems (Pham et al. 2019). It is estimated that mangrove ecosystems globally contribute to storing 10% of total carbon on the Earth (Dinilhuda et al. 2020). Mangrove trees can store carbon an average of 6-8 Mg CO_2 e/ha, which is higher than any terrestrial tropical forests (Harishma et al. 2020). Nonetheless, mangrove species' capacity to sequester and store carbon differs (Purnomo 2020). The carbon sequestration by mangrove plants mainly occurs in the leaves, branches, stems, roots, and soils. The total carbon storage of a mangrove ecosystem is positively correlated with the extent and condition of the mangrove forest, meaning the higher the extent and the better condition of the mangrove forest, the greater the carbon stock in a unit area, and vice versa (Hong et al. 2017).

While many studies assess the carbon stock of mangrove forests, a context-specific assessment is needed to enrich the existing studies in this field. One mangrove forest which is little known regarding its carbon stock potential is in Ayah Village, Ayah Sub-district, Kebumen District, Central Java Province, Indonesia. The mangrove forest in this village is located at the mouth of the Bodo River, which flows toward the Indian Ocean. The mangrove forest is already developed as an ecotourism object in the Kebumen region, with facilities including gazebos, boats, photo spots, food stalls, parking areas, toilets, and prayer rooms. Various faunas are found in the Ayah Mangrove Forest, including fishes, crustaceans, birds, and mollusks. However, the flora includes *Rhizophora mucronata*, *Sonneratia caseolaris*, *Avicennia marina*, *Rhizophora apiculata*, *Acanthus ebracteatus*, *Acrostichum aureum*, *Bruguiera gymnorrhiza* and *Nypa fruticans* (Halizah and Puspitasari 2017). This study aimed to investigate the aboveground carbon stored in vegetation occurring in three mangrove zones (i.e., seaward, middle and landward zones) in Ayah Village, Kebumen, Central Java, Indonesia.

MATERIALS AND METHODS

Study area

This study was conducted in the mangrove forest in Ayah Village, Ayah Sub-district, Kebumen District, Central Java Province, Indonesia (Figure 1). The study area has geographical coordinates of 7°43'09.5"S and 109°23'32.9"E. The mangrove forest is located at the mouth of Ijo River, close to Logending Beach, a popular tourist spot in the region.

Figure 1. Map of study location at mangrove forest in Ayah Village, Ayah Sub-district, Kebumen District, Central Java, Indonesia

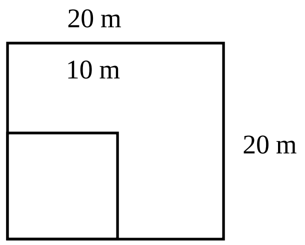

Figure 2. Plot illustration

Data collection procedure

Data collection was conducted in November 2022. Vegetation sampling used nested plots by establishing observation plots, each plot measuring 20×20 m to collect data for the tree stage and 10×10 m for the pole stage (Figure 2). The tree stage is defined as a woody plant with Diameter Breast Height (DBH) >20 cm, while poles are young trees with DBH 10-20 cm. Ayah Mangrove Forest has three zones, namely seaward, middle and landward. Within each zone, there were observation plots. The species name was identified at each plot, and the DBH and plant height were measured. The species name was determined based on the information from the local community and cross-checked with relevant literature.

Data analysis

Data on the diversity and zonation of mangrove plants were analyzed descriptively. Aboveground biomass was calculated using an allometric equation as presented in Table 1, and carbon stock was estimated following National Standardization Agency (2011) as follows:

$$C_n = \frac{C_x}{1.000} \, x \, \frac{10.000}{l_{sub-plot}}$$

Where: Cn= carbon stock per hectare (MgC/ha), Cx= carbon per subplot (Kg), *Isub-plot*= extent of subplot (m²)

RESULTS AND DISCUSSION

Ayah Mangrove Forest can be considered multifunctional mangrove-based ecotourism (Pratama and Wibawanto 2019). The area of the Ayah Mangrove Forest is organized based on species which is used as an educational tool for visitors. The mangrove density is high, with mangrove classification arranged by planting year. The oldest mangrove plant was planted in 1995 and is still present nowadays. The research results documented 11 species belonging to 8 families across the observation plots. Among them, seven species were true mangroves: *N. fruticans, Avicennia alba, A. marina, Sonneratia alba, Xylocarpus granatum, R. apiculata*, and *R. mucronata*, which belong to 5 families, namely Arecaceae, Acanthaceae, Lythraceae, Meliaceae, and Rhizoporaceae. The other 4 species were mangrove associates: *Cocos nucifera, Acacia mangium, Barringtonia asiatica*, and *Hibiscus tiliaceus* from 4 families (Arecaceae, Fabaceae, Lecythidaceae, and Malvaceae) (Figures 3 and 4).

The number of species in this study is higher than that in Jakarta Bay, Indonesia, which consisted of 3 families with 6 species, namely *S. alba*, *A. alba*, *Rhizophora stylosa*, *A. marina*, *R. apiculata* and *R. mucronata* (Slamet et al. 2020). However, the richness is lower than the mangrove forest in Segara Anakan, Cilacap, Indonesia with 24 species, consisting of ten species of a true mangrove, i.e., *A. marina*, *S. caseolaris*, *S. alba*, *B. gymnorrhiza*, *Aegiceras corniculatum*, *R. mucronata*, *R. apiculata*, *N. fruticans*, *Ceriops tagal*, *Heritiera littoralis* belonged to six families (Acanthaceae, Sonneraticeae, Rhizophoraceae, Myrsinaceae, Arecaceae, dan Strecaliaceae), while the other 14 species were non-mangrove (Widyastuti et al. 2018).

Figure 3. The condition of mangrove vegetation in Ayah, Kebumen, Central Java, Indonesia

Table 1. Allometric equations used to calculate aboveground biomass of each mangrove species

Species	Equation	References
True mangroves		
Avicennia alba	AGB = $0.079211 x D^{2.470895}$	Tue et al. (2014)
Avicennia marina	AGB = $0.185x(D^{2.352})$	Dharmawan and Siregar (2008)
Nypa fruticans	AGB=$0.222x(D^{2.7048})$	Rahman et al. (2020)
Rhizopora apiculata	AGB=$10^{(-1.315+2.614*LOG(D))}$	Amira (2008)
Rhizopora mucronata	AGB =$0.045x(D)^{2.868}$	Gevana and Im (2016)
Sonneratia alba	AGB = $0.258 \times D^{2.287}$	Kusmana et al. (2018)
Xylocarpus granatum	logAGB =-0,763 + 2,23 logD	Tarlan (2008)
Mangrove associates		
Acacia mangium	AGB = $0.199 \, D^{2.148}$	Siregar and Heriyanto (2010)
Cocos nucifera	AGB= 4.5+7.7+H (kg/tree)	Hairiah et al. (2010)
Hibiscus tiliaceus	AGB = $0.168 \times \rho \times D^{2.47}$	Chave et al. (2005)
Barringtonia asiatica	$0.0661xD^{2.591}$	Ketterings et al. (2021)

Note: D: Diameter at breast height, H: height and ρ: wood density (Word Agroforestry Center 2022)

Figure 4. Mangrove species at three different zones in Ayah Mangrove Forest: A. *Rhizophora mucronata* in the seaward zone; B. *R. mucronata* in the middle zone; C. *R. mucronata* in the landward zone

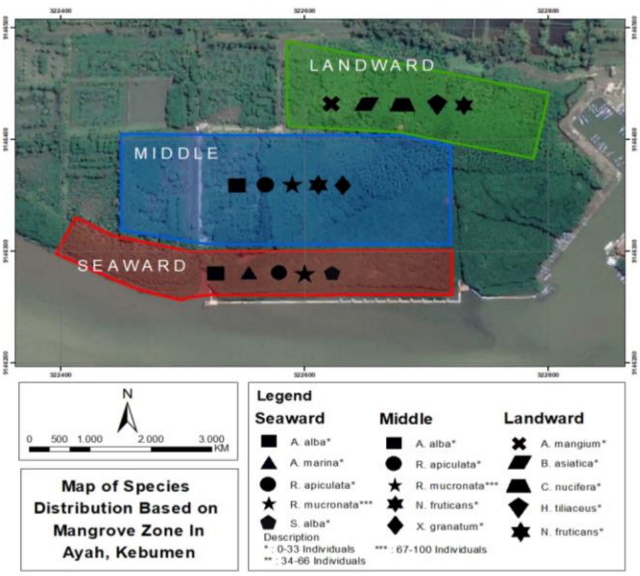

Figure 5. Map of mangrove zonation and the composing species in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

The Important Value Index (IVI) is commonly used to show the dominance of species within a vegetation community (Yuliana et al. 2019). In Segara Anakan, Cilacap, the species with the highest IVI was *A. marina* (Widyastuti et al. 2018), while in the Ayah Mangrove Forest, the most important species was *Rhizophora* sp. This species has a high adaptation ability in various environmental conditions. It is easy to regenerate naturally as the falling propagules will plant themselves in the soil with the shoots facing upwards. Besides naturally regenerating, the presence of *Rhizophora* sp. in the Ayah Mangrove Forest was also from planting conducted by the management. The second most dominant species in the Ayah Mangrove Forest was *Avicennia* sp. which grows naturally as well as being planted under mangrove rehabilitation programs conducted in Bantul District, Yogyakarta, Indonesia (Purwaningrum, 2020), Tugu Sub-district, Semarang, Indonesia (Martuti 2013), and Subang, West Java, Indonesia (Siringoringo et al. 2018).

Zonation in the mangrove ecosystem is formed due to the different abilities of mangrove species to respond to environmental conditions (Mughofar et al. 2018). Generally, the mangrove ecosystem can be classified into three zones based on water level and intertidal condition: seaward, middle, and landward (Sunarni et al. 2019). The Seaward zone is located closest to the sea, while the landward zone is located closest to the land, and in between the two zones, there is the middle zone (Figure 5).

In the seaward zone of the Ayah Mangrove Forest, all plant species documented were true mangrove consisting of five species (i.e., *A. alba*, *A. marina*, *R. apiculata*, *R. mucronata*, *S. alba*) with the dominance of *R. apiculata* and *R. mucronata*. The dominance of species from the general of *Rhizophora* is due to the high adaptability to a wide range of salinity, temperature, pH, tidal waves, and organic matter (Rosalina Rombe 2021). The seaward zone has a high salinity level with substrates suitable as the habitat of *R. apiculata* (Dharmawan et al. 2016).

The middle zone is the transition zone between the seaward and landward zones. In this zone, there were five true mangrove species, namely *A. alba*, *R. apiculata*, *R. mucronata*, *X. granatum,* and *N. fruticans*. In the middle zone, there were a significant number of *R. mucronata*, but a species not found in the seaward zone was documented in the middle zone, i.e., *N. fruticans.* In this zone, *Rhizophora sp.* was found in the intertidal area with sandy substrates (Syah, 2020). The *N. fruticans* in the middle zone are likely caused by the significant number of seeds produced from this species (Eddy et al. 2019).

The landward zone is commonly used as an area for rehabilitation programs using species from the Rhizophoraceae family (Pimple et al. 2022). The vegetation community in this zone is a transition of true mangroves into terrestrial plants (Luo et al. 2022). Plant species in the seaward zone are often found in sandy beach ecosystems, such as *B. asiatica*, *Pandanus tectorius*, and *Terminalia catappa* (Sumanto 2020). The seaward zone in the Ayah Mangrove Forest is composed of four species, i.e., *C. nucifera*, *H. tiliaceus*, *B. asiatica*, *A. mangium*, and *N. fruticans*. The three species other than *N. fruticans* are categorized as mangrove associates. In this zone, there was also a plant collection garden and nurseries.

Aboveground biomass

In Ayah Mangrove Forest, there were five species at the tree stage and ten species at the pole stage. The total aboveground biomass of the vegetation in the mangrove forest was 88529.43 MgB/ha, composed by 50298.78 MgB/ha of aboveground biomass at the tree stage and 38230.65 MgB/ha at the pole stage (Table 2). At the tree stage, species with the highest aboveground biomass was *R. mucronata* with 32787.33 MgB/ha, while the lowest was *C. nucifera* with 72.14 MgB/ha. At the pole stage, species with the highest amount of aboveground biomass was *R. mucronata* with 25550.12 MgB/ha, while the lowest was *H. tiliaceus* with 54.70 MgB/ha. Aboveground biomass was calculated using DBH as a predictor in which the larger the DBH, the greater the amount of aboveground biomass. In addition, the total biomass in a unit area is affected by the number of individuals (density), implying that the more density of mangrove plants, the greater the amount of aboveground biomass. Biomass also has positive correlation with carbon stock, thus a mangrove with high biomass will have a great carbon storage (Irsadi et al. 2017).

The seaward zone had the greatest amount of aboveground biomass with 29324.07 MgB/ha (Table 3). In this zone, there were five species (i.e., *A. alba, A. marina, R. apiculata, R. mucronata,* and *S. alba*) with the largest AGB was contributed by *R. mucronata.* The middle zone had AGB of 52776.62 Mg/ha which was contributed by *A. alba, R. apiculata, R. mucronata, N. fruticans, and X. granatum* with *N. fruticans* had the largest share with 15576.87 MgB/ha. The lowest amount of AGB was found in landward zone with only 6428.87 MgB/ha with the presence of mangrove associates (*C. nucifera, H. tiliaceus, B. asiatica* and *A. mangium*) and true mangrove *N. fruticans*. In this zone, *N. fruticans* had the largest share of ABG with 5689.65 MgB/ha.

Carbon stock

The results of analysis of carbon stock in Ayah Mangrove Forest is presented in Table 4 which shows the minimum, maximum, average and total carbon stock across the plots. Based on Table 3, carbon stock differed among species. In term of minimum value, species with the highest amount of carbon stock was *X. granatum* with 265.45 MgC/ha while the lowest was *R. apiculata* with 2.57 MgC/ha. In term of maximum value, *C. nucifera* had the highest carbon stock with 351.6 MgC/ha and *H. tiliaceus* had the lowest carbon stock with 5.25 MgC/ha. Therefore, it can be inferred from Table 4 that overall *C. nucifera* had the highest carbon stock with 351.6 MgC/h while *R. apiculata* had the lowest with 2.57 MgC/ha.

We found that total carbon stock differed among mangrove zones. In the seaward zones, the total carbon stock was 43.06 MgC/ha which was contributed by five true mangrove species, i.e., *A. alba* (4.75 MgC/ha), *A. marina* (5.75 MgC/ha), *R. apiculata* (6.28 MgC/ha), *R. mucronata* (15.20 MgC/ha), and *S. alba* (11.07 MgC/ha) (Table 5). In the middle zone, the total carbon stock was 197.42 MgC/ha, accumulated from five true mangrove species, namely *A. alba* (3.51 MgC/ha), *N. fruticans* (45.76 MgC/ha), *R. apiculata* (8.57 MgC/ha), *R. mucronata* (14.82 MgC/ha) and *X. granatum* (124.76 MgC/ha). The landward zone had total carbon stock of 186.00 MgC/ha which was contributed by *A. mangium* (5.35 MgC/ha), *B. asiatica* (5.42 MgC/ha), *C. nucifera* (6.87 MgC/ha), *H. tiliaceus* (134.94 MgC/ha) and *N. fruticans* (33.43 MgC/ha).

In term of total carbon stock, the highest was *N. fruticans* with 611.93 MgC/ha followed by *X. granatum* with 265.45 MgC/ha while the lowest was *H. tiliaceus* with 4.44 MgC/ha followed *N. fruticans* with 11.38 MgC/ha. The biomass and carbon stock differed among species which is affected by the different ability of each species in sequestering carbon inferred from DBH, wood density and height (Mahmood et al. 2020). Carbon sequestration can be defined as the capacity of a plant to capture and store carbon for a long period in its body parts (Schmidt et al. 2019).

Table 2. Aboveground biomass of each species at tree and pole stages in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Spesies	**Biomassa (MgB/ha)**		**Total**
	Trees	**Poles**	**(MgB/ha)**
Nypa fruticans	15576.87	5689.65	21266.52
Rhizophora mucronata	32787.33	25550.12	58337.45
Rhizophora apiculata	1459.00	1869.92	3328.92
Avicennia marina	-	489.66	489.66
Xylocarpus granatum	-	2654.51	2654.51
Avicennia alba	298.91	707.49	1006.4
Sonneratia alba	-	706.88	706.88
Cocos nucifera	72.14	278.50	350.64
Barringtonia asiatica	-	115.40	115.40
Hibiscus tiliaceus	104.53	54.70	159.23
Acacia mangium	-	113.82	113.82
Total	50298.78	38230.65	88529.43

Table 3. Aboveground biomass in each zone in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Zone	**Species**	**Biomass (MgB/ha)**
Seaward	*Avicennia alba*	707.49
	Avicennia marina	489.66
	Rhizophora apiculata	1869.92
	Rhizophora mucronata	25550.12
	Sonneratia alba	706.88
	Total	**29324.07**
Middle	*Avicennia alba*	298.91
	Nypa fruticans	15576.87
	Rhizophora apiculata	1459.00
	Rhizophora mucronata	32787.33
	Xylocarpus granatum	2654.51
	Total	**52776.62**
Landward	*Acacia mangium*	113.82
	Barringtonia asiatica	115.40
	Cocos nucifera	350.64
	Hibiscus tiliaceus	159.23
	Nypa fruticans	5689.65
	Total	**6428.74**

Table 4. The minimum, maximum, average and total carbon stock of each species in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Species	Total plots	Carbon stock (MgC/ha)			
		Min	Max	Average	Total
Rhizophora mucronata	109	13.07	39.09	0.7	76.33
Nypa fruticans	12	5.86	80.25	527.05	611.93
Xylocarpus granatum	1	-	-	-	265.45
Avicennia marina	4	4.35	7.35	19.77	79.1
Avicennia alba	8	9.74	16.83	11.56	18.09
Rhizophora apiculata	16	2.57	18.23	3.18	31.84
Sonneratia alba	3	6.23	8.33	6.45	19.35
Barringtonia asiatica	1	-	-	-	11.54
Cocos nucifera	4	12.73	351.6	13.14	13.86
Hibiscus tiliaceus	3	3.57	5.25	2.47	4.44
Acacia mangium	1	-	-	-	11.38
Total					1.143.31

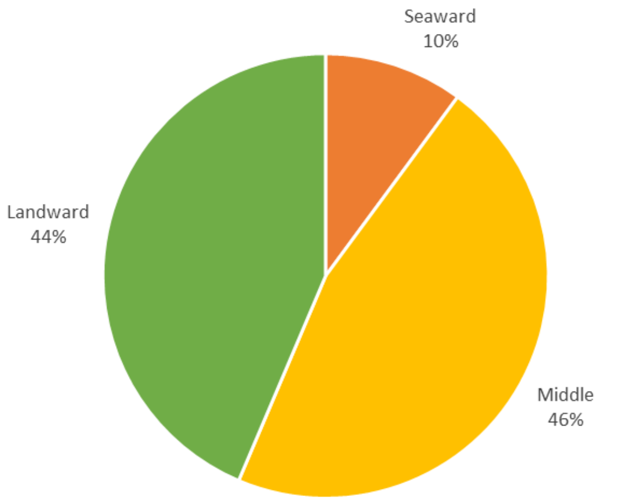

Figure 6. Proportion of total carbon stock of each zone in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Table 5. Carbon stock in each zone in Ayah Mangrove Forest, Kebumen, Central Java, Indonesia

Zone	Species	Carbon Stock (MgC/ha)
Seaward	*Avicennia alba*	4.75
	Avicennia marina	5.75
	Rhizophora apiculata	6.28
	Rhizophora mucronata	15.20
	Sonneratia alba	11.07
	Total	**43.06**
Middle	*Avicennia alba*	3.51
	Nypa fruticans	45.76
	Rhizophora apiculata	8.57
	Rhizophora mucronata	14.82
	Xylocarpus granatum	124.76
	Total	**197.42**
Landward	*Acacia mangium*	5.35
	Barringtonia asiatica	5.42
	Cocos nucifera	6.87
	Hibiscus tiliaceus	134.94
	Nypa fruticans	33.43
	Total	**186.00**

As a mangrove forest, the carbon contained in the aboveground vegetation in Ayah beach can be categorized as blue carbon. This term refers to all carbon stored in coastal and marine ecosystems in which many studies showed that these ecosystems could absorb carbon greater than terrestrial ecosystems, including forests. Ecosystems producing blue carbon include mangroves, tidal swamps, seagrass, coral reefs, etc. In mangrove forests, carbon is not only stored in the vegetation but also stored in the soil sediment (Krauss et al. 2014). When combined, the carbon stored in mangrove vegetation and soil makes this ecosystem the largest carbon sink on Earth (Hamilton and Friess 2018).

There were four mangrove species which occurred in more than one zone, yet the similar species might have different carbon stock among different zones. Such species included *A. alba*, *R. apiculata*, and *R. mucronata* which occurred on the seaward and middle zones, and *N. fruticans* which occurred on the middle and landward zone. Such a difference is likely caused by the number of individuals of each species, number of plots, DBH and environmental conditions of the habitat where the plant grows.

The middle zone had the highest carbon stock compared to other zones which contributed to 46% of total carbon stock in all zones (Figure 6). The *X. granatum* with carbon stock of 124.76 MgC/ha make the total carbon stock in the middle zone was higher than the other zones. The landward zone shared 44% of total carbon of all zones with *H. tiliaceus* as the species with the largest contribution of carbon stock in this zone with 134.94 MgC/ha. The high number of individuals of each species and the size of the DBH in the seaward zone was one factor that cause the high carbon stock in this zone.

The seaward zone had the lowest total carbon stock compared to other zones with only a proportion of 10% of total carbon across all zones. On the other hand, *R. mucronata* had the largest carbon stock in this zone, with 15.20 MgC/ha. The low carbon stock in the landward zone is likely caused by the very low presence of mangrove species compared to other zones. In conclusion, the Ayah Mangrove Forest can provide ecosystem services in the form of carbon stock. The total aboveground biomass in the Ayah Mangrove Forest was 88529.43 MgB/ha, equal to

1143.31 MgC/ha carbon stock. The great amount of carbon stored in the Ayah Mangrove Forest implies the potential of the forest to contribute to climate change mitigation. The findings of this study reiterate the importance of conserving mangrove forests as an effective way to reduce carbon emissions which are the major cause of global warming. In addition, expanding the extent of mangrove forests through rehabilitating degraded mangrove forests and better managing existing mangrove forests would enhance the mangrove ecosystem's capacity for sequestering and storing carbon.

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Short Communication: Efficiency economic of whiteleg shrimp *Litopenaeus vannamei* (Boone 1931) cultivation with a household scale biofloc system

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Abstract. *Bidayani E, Valen FS. 2023. Short Communication: Efficiency economic of whiteleg shrimp* Litopenaeus vannamei *(Boone 1931) cultivation with a household scale biofloc system. Indo Pac J Ocean Life 7: 156-160.* Aquaculture is one of the necessary sectors for fisheries in Indonesia because it can contribute to national food security, income, employment development, and foreign exchange earnings. Shrimp is a non-oil and gas export commodity that plays a crucial role. Besides the high price, shrimp has a large market in various countries Whiteleg shrimp *Litopenaeus vannamei* (Boone 1931) cultivation is synonymous with large capital. However, with innovation, people can cultivate whiteleg shrimp in their yards with small capital. This study aims to analyze the business efficiency of a household-scale shrimp farming business with a biofloc system. The research method is a case study in the Bio Ebi Micro Fish Cultivator Group, Air Mawar Village, Air Itam District, Pangkalpinang City, Bangka Belitung Islands Province, Indonesia. Collecting data is observation and interviews; the data analysis method is descriptive. The study's results show the acceptance of cultivators per cycle is 172,800,000 IDR with an average production yield of 1.8 tons/cycle with a selling price of 96,000 IDR/kg. The efficiency of household-scale shrimp farming with a biofloc system is 2.39. Based on these results, household-scale whiteleg shrimp cultivation is feasible to develop in coastal areas.

Keywords: Bangka, biofloc, cultivation, efficiency, household, whiteleg

INTRODUCTION

Aquaculture can be implemented in freshwater, brackish water, and seawater using various facilities and production methods. Cultivation systems range from extensive to intensive, depending on stocking density, level of input, and management level. Brackish water cultivation is quite popular in Indonesia. One of them is shrimp farming. Shrimp farming contributes to the country's foreign exchange in Indonesia (Rajikkannu et al. 2020). Shrimp farming has increased rapidly in the last decade, and cultured shrimp continues to dominate the international seafood market (Iba et al. 2014). Some farmers suffered losses due to lack of technical knowledge in shrimp aquaculture, environmental carrying capacity, ecological and economic feasibility (Djumanto and Rustadi 2016).

In Indonesia, pond farmers have long practiced shrimp farming because shrimp is a prime aquaculture commodity in the fisheries sector that can increase foreign exchange through exports of fishery commodities. The high demand for shrimp at home and abroad makes Indonesia the fourth producer in the world because Indonesia has an extensive area and natural resources supporting shrimp farming development. Given the scope and potential for future expansion of this industry, the need for continuing regulation for safeguarding and improving shrimp aquaculture

Whiteleg shrimp *Litopenaeus vannamei* (Boone 1931) has officially been released as superior varieties and is disease resistant and expected can increase the chances of doing aquaculture again. In addition, it also aims to enrich and add to the alternative types of cultivated shrimp that have the potential to be developed.

Bangka Island is a coastal area in the Province of the Bangka Belitung Islands which has a coastline of 1,200 km. The potential of fisheries and marine resources provides an opportunity to increase aquaculture production quite large (Mahmud et al. 2021; Setiyowati et al. 2022). Data from the Department of Marine Affairs and Fisheries of the Bangka Belitung Islands Province (2021), whiteleg shrimp production in this region in 2018-2020 increased by 1,931 tons to 11,333 tons or an increase of 318%. Household-scale shrimp farming is a small-scale business utilizing a narrow yard or land as a business location (Efani et al. 2020); the family can do this business as the executor (Sutaman 1993). Whiteleg shrimp have high productivity, shorter maintenance time, relatively fast growth, and are easy to cultivate (Amri 2013).

Semi-intensive shrimp ponds with a high abundance of plankton at the time of fry stocking had a better survival rate (Katmoko et al. 2021), which was 92.5% with a feed conversion value of 1.3. While the abundance of plankton is low, the survival rate is 40.13%, and feed conversion is 1.9 (Pratama et al. 2017). Factors influencing whiteleg shrimp culture's success include pH, salinity, DO content, ammonia, H2S, water brightness, and plankton content (Hudi and Shahab 2005). The shrimp growth rate is influenced by feed supply, fertilization, aeration, and shrimp survival (Gunarto and Hendrajat 2008).

Shrimp cultivation with a biofloc system in the Micro Bio Ebi Fish Cultivator Group (Pokdakan) in Air Mawar Village, Air Itam District, Pangkalpinang City, Bangka Belitung Islands Province uses a round pond measuring 2 x 3 m. According to Gunarto et al. (2012), shrimp survival and growth in ponds grown with biofloc were better (Ogello et al. 2021; Nisar et al. 2022), and the feed conversion value was lower.

Biofloc is easily formed in ponds using high-density polyethylene (HDPE) plastic (Saenphon 2005). The shrimp will eat the biofloc formed in the pond (Manan et al. 2020; Mansour et al. 2022). According to Gunarto and Suryanto (2011), there are 15 types of amino acids found in biofloc. Biofloc also contains vitamins that can replace vitamins supplied through commercial feed (Tacon et al. 2002). Biofloc also contains enzymes that can help the digestive process of shrimp feed so that shrimp grow faster (Moss et al. 2001).

The main principle of bioflocs is to grow organisms, especially heterotrophic bacteria, in pond water to absorb ammonia pollutant components to be further converted into bacterial protein. It can be used as a feed substitution for farmed whiteleg shrimp (Gunarto et al. 2012). This biofloc technology can reduce the cost of shrimp feed (Schryver et al. 2008; Kumar et al. 2018). This study analyzes business efficiency in household-scale shrimp farming with a biofloc system.

MATERIALS AND METHODS

This research was conducted from January to March 2022 at Pokdakan Mikro Bio Ebi, Air Mawar Village, Pangkalbalam Sub-district, Pangkalpinang City, Bangka Belitung Islands, Indonesia. Determination of the location purposively considering that Pokdakan Micro Bio Ebi has successfully carried out household-scale shrimp *L. vannamei* farming with a biofloc system.

This study uses a survey method with a case study approach. Data collection methods are observation, interviews, and literature study. The quantitative descriptive data analysis method uses the following formula (Soekartawi 2003):

R/C= TR:TC

R/C: Business efficiency
TC: Total Cost

Business efficiency criteria:
R/C > 1 = Profitable business
R/C = 1 = Break-even work
R/C < 1= Business loss

RESULTS AND DISCUSSION

Cost components are grouped into two parts: Investment and operational costs. Investment costs must be incurred to obtain production factors used in the production process. Operational costs are the amount of funds spent for the production process.

Investment cost

Investment costs are incurred once during the project's life to obtain benefits until it is economically no longer profitable. Investment costs for whiteleg shrimp farming include land, pond-making plots, guard houses, generators, windmills, pumps, scales, and water quality equipment. This investment value results from a reassessment of investments that were invested at the beginning of the business in 2018. The entire capital comes from their own capital. Details of investment components can be seen in Table 1.

Investment costs are the initial costs incurred when running a business, namely in the first year of business, where the amount is relatively large and may be exhausted. The investment costs incurred in the whiteleg shrimp rearing business at Pokdakan Mikro Bio Ebi are 48,000,000 IDR. It can be seen that the largest percentage is windmills, HDPE plastics, and guardhouses from all investment costs. If you are allowed, these three higher costs due to the windmills, HDPE plastic, and guard houses greatly affect the smoothness of the production process and can be used for a long time. Investment costs are invested in a business to obtain profits in the future period, namely during the business's life or as long as the business is running.

Production cost

Production costs are needed to process inputs to produce several outputs. The business costs incurred in whiteleg shrimp cultivation at Pokdakan Mikro Bio Ebi consist of fixed and variable costs.

Fixed cost

Fixed costs are costs that are fixed in number and do not depend on the volume of production. Fixed costs are costs incurred by a business; the size of the production of a business does not influence these costs. If you are allowed, the fixed-cost components required by the two Pokdakan Micro Bio Ebi cultivators in rearing whiteleg shrimp could be depreciated for many years (depreciable costs). The following results of calculating the fixed costs of the whiteleg shrimp rearing business at Pokdakan Mikro Bio Ebi are presented in Table 2.

Fixed costs for whiteleg shrimp farming include depreciation costs. The amount of fixed costs incurred for whiteleg shrimp ponds in Pokdakan Mikro Bio Ebi can be seen in Table 2, fixed costs based on the results obtained in Pokdakan Mikro Bio Ebi are 6,350,000 IDR. Fixed costs are usually the first costs cultivators incur to prepare for the cultivation process. Fixed costs are also types of costs that are always fixed in number or do not change even during a certain operating time range or the level of production capacity changes (Daulay et al. 2019).

Variable cost

Variable costs are costs incurred by cultivators in their business activities; if you are allowed, these costs differ according to production variability, which is said to be variable costs. The variable costs of whiteleg shrimp farming can be seen in Table 3.

Table 3 shows the total variable costs incurred per cycle for the whiteleg shrimp rearing business at Pokdakan Mikro Bio Ebi which are 66,000,000 IDR. Variable costs are costs that depend on the volume of production produced. Variable costs for whiteleg shrimp farming include feed, fry, probiotics, and others, and also the wages of on-call labor at harvest. The number of variable costs incurred for shrimp farming can be seen in Table 3.

Table 3 shows that the largest percentage is feed, which is 65.2% of all variable costs because feed is an important component in cultivation. This greatly affects the income of the cultivator's business because the feed cost incurred for this business is more than 60%. The feed cost is very large, and this is because the feed used by cultivators is not produced independently; the cultivators still have to buy feed whose price is relatively high, which makes variable costs high.

Therefore, feed is the biggest financing factor spent in rearing activities. The costs incurred for feed in the aquaculture business reach 60-70% of the total variable cost. The costs incurred for providing shrimp feed do not rule out the possibility that many cultivators still have to spend quite a lot of money to construct the pond. According to Perius (2011), feed is a source of material and energy to support the survival and growth of fish, but on the other hand, feed is the largest component (50-70%) of production costs. The total operating costs are presented in Table 4.

Revenue. Revenue is the receipt of production from the sale of its output. Therefore, the results are multiplied by the output's selling price to calculate the total revenue obtained from the output or production. The feasibility study was conducted to determine how much yield was obtained in one cycle of whiteleg shrimp rearing in Pokdakan Mikro Bio Ebi, which could be accepted. The results of the feasibility study can be seen in Table 5.

Based on Table 5, it can be seen that the revenue per cycle cultivators is 172.8 million IDR. The average yield in this cultivation business reaches 1.8 tons/cycle with a selling price of 96,000 IDR/kg. This indicates that this business is feasible to develop because the business revenue exceeds the total costs incurred during the cultivation process. The revenue of a business will change according to the total production; the higher the total production, the more revenue will increase (Ahmad 2019). The acceptance of this cultivation business can be concluded that it is feasible to be developed because the cultivation business's total revenue is greater than the total cost incurred for the cultivation business.

Table 1. Components of investment in the whiteleg shrimp pond

Component Cost	Unit Amount	Quantity	Cost (IDR)	Percentage
Water wheel	Unit	3	15,000,000	31.25%
Guardhouse	Unit	1	10,000,000	20.83%
Gensets (gasoline generator)	Unit	1	2,000,000	4.17%
Plastic HDPE (Geomembran plastic Hdpe UV)	Roll	1	5,000,000	10.42%
Central pipe	Unit	2	2,000,000	4.17%
Water pumps	Unit	2	4,000,000	8.33%
Excavator rental fee	Unit	1	5,000,000	10.42%
Harvesting nets	Unit	1	500,000	1.04%
Resun Lp 100	Unit	2	3,000,000	6.25%
Round pool tarpaulin	Unit	1	500,000	1.04%
water tank	Unit	1	1,000,000	2.08%
Total			48,000,000	100%

Table 2. Fixed costs of whiteleg shrimp farming business per cycle

Description	Fixed Costs (IDR/cycle)
Ferris wheel	2,940,000
Gensets	360,000
Plastic Hdpe	500,000
Central pipe	370,000
Water pump	760,000
Harvest nets	100,000
Resun Lp 100	560,000
guardhouse	600,000
Water tendons	160,000
Total	6,350,000

Table 3. Variable costs of whiteleg shrimp ponds per cycle

Description	Total Cost (IDR/cycle)	Percentage (%)
Seed	6,000,000	9.10
Probiotics and drugs	8,000,000	11.7
Electricity	5,000,000	7.38
Feed	43,000,000	65.2
Employee salary wages	4,000,000	6.52
Total	66,000,000	100

Advantage. The profit of a business can be seen from the result of the difference between the total value of the revenue minus the total cost of expenditure. Profits from the whiteleg shrimp rearing business at Pokdakan Mikro Bio Ebi can be seen in Table 6. Based on this table, the average profit of the whiteleg shrimp rearing business in Pokdakan Mikro Bio Ebi is 100,450,000 IDR/cycle. That stated the whiteleg shrimp expanding business at Pokdakan Mikro Bio Ebi was feasible to develop because the profits were quite large. In addition, the expanding of whiteleg shrimp in this cultivation business for 1 cycle takes 120 days to harvest. A business is said to be profitable and feasible to develop if the revenue obtained exceeds the total costs and implicit costs incurred (Sukirno and Sadono 2012). So it can be concluded that this cultivation business is feasible to be developed because the result of the difference between revenue and total costs and implicit costs shows a positive number.

R/C Rasio. Revenue Cost Ratio (R/C ratio) is a calculation to compares the total revenue with the total value of costs that have been incurred during the production process. Calculating the R/C ratio is also a way to determine whether a business action is feasible. The income from the whiteleg shrimp rearing business at Pokdakan Mikro Bio Ebi can be seen in Table 7.

Table 4. The total cost of whiteleg shrimp rearing business per cycle

Type of Cost	Value (IDR/cycle)
Fixed fee	6,350,000
Variable cost	66,000,000
Total cost	72,350,000

Table 5. Revenue from whiteleg shrimp rearing business per cycle

Description	Production/cycle
Production (ton)	1.8
Price (IDR/kg)	96,000
Revenue (IDR/cycle)	172,800,000

Table 6. Profits from the whiteleg shrimp rearing business per cycle

Description	IDR/cycle
Revenue	172,800,000
Total cost	72,350,000
Profit	100,450,000
Total	100,450,000

Table 7. Results of the R/C ratio of whiteleg shrimp cultivation in Pokdakan Micro Bio Ebi per cycle

Description	Quantity/cycle (IDR)
Revenue	172,800,000
Total cost	72,350,000
R/C Ratio	2.39

From the calculation results above, the R/C ratio value is 2.39. Because the R/C value is > 1, it concluded that the whiteleg shrimp rearing business at Pokdakan Mikro Bio Ebi is profitable and feasible. In other words, the R/C Ratio value of 2.39 means that for every 100,000 IDR spent, the whiteleg shrimp rearing business in Pokdakan Mikro Bio Ebi gets a profit of 138,000 IDR. The value of the R/C ratio is 2.39, which means that if each expenditure is 100 IDR, then the cultivator will generate revenue of 2.39 IDR (with a profit of 138 IDR); the greater the R/C value, the greater the profit from the business. According to Vijayanti and Yasa (2016), entrepreneurs should improve entrepreneurial behavior by expanding insight and information to increase revenue and efficiency. According to Nugroho et al. (2021), some freshwater shrimp species in Indonesian waters are potentially cultivated. The types of shrimp cultivated widely in Indonesia are whiteleg shrimp. According to Renanda et al. (2019), whiteleg shrimp is a new variety with some advantages, including more resistance or resistance to disease and low environmental quality, high stocking density, and shorter rearing time, around 90-100 days per cycle.

Discussion

The efficiency economic of household-scale shrimp farming with a biofloc system is 2.39. Based on these results, household-scale whiteleg shrimp cultivation is feasible to develop in coastal areas. According to Crab et al. (2012), biofloc technology enhances water quality in aquaculture by balancing carbon and nitrogen in the system. The technology has recently gained attention as a sustainable method to control water quality, with the added value of producing proteinaceous feed in situ. Furthermore, Hidayat (2017) and Almuqaramah et al. (2018), the biofloc system has a higher whiteleg growth rate (9.85%) and feed efficiency (37.33%). In addition, Muhammad (2013), probiotics in the digestive tract secrete protease and amylase enzymes.

This research is in line with Simanjuntak and Sudaryono (2016) biofloc technology is one of the solutions to environmental problems and can increase aquaculture production. According to Supono et al. (2021), intensively cultivating *L. vannamei* with biofloc systems is one of the most efficient ways to reduce shrimp cost production. The biofloc can be used as feed substitution for *L. vannamei* cultured. Applying the biofloc system in commercial ponds is still experiencing many obstacles, so it is not optimal in supporting the success of cultivation. One factor that determines the success of shrimp farming with a biofloc system is the determination of the right organic carbon source.

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