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THE POTENTIAL USE OF CORAL REEF HABITAT MAPPING IN SUPPORTING ECOTOURISM DEVELOPMENT IN LOMBOK, INDONESIA

Eghbert Elvan AMPOU[1,*], Rinny RAHMANIA[2], Rizki HANINTYO[1], Novia Arinda PRADISTY[1], Widodo SETIYO PRANOWO[3]

[1] Research Center for Oceanography, National Research and Innovation Agency, Republic of Indonesia
[2] Research Center for Ecology and Ethnobiology, National Research and Innovation Agency, Republic of Indonesia
[3] Research Center for Climate and Atmosphere, National Research and Innovation Agency, Republic of Indonesia

Abstract

Many studies related to marine ecotourism and coral reefs have been carried out in several locations in Indonesia. In TWP Gitanada, West Lombok, NTB coral reef habitat inventory and mapping was conducted in June 2021 by using Sentinel 2A satellite imagery and field observation. Geomorphologically, the TWP Gitanada area consisted of fringing reefs made of reef flat, fore reef/reef crest, reef slope, reef wall,and patch reef. The coral reef area is 450 ha and consists of > 200 types of coral reef benthic habitat, dominated by scleractinian corals (Acropora, Montipora, Porites and their associations with less dominant genera). All coral reef habitat data is presented here in a format which is suitable to attract the attention of visitors or tourists in understanding and supporting ecotourism development, which uses TWP Gitanada as a general case study which is relevant for all marine conservation and potential marine conservation throughout Indonesia. The information is helpful to identify which areas could be prioritized for conservation under the criteria of habitat richness or for further development by relevant stakeholders.

Keywords*: Coral reef; Habitat mapping; Marine ecotourism; NTB Indonesia*

Introduction

Indonesia harbors one of the greatest coral reef biodiversity worldwide, as part of the Coral Triangle, with Malaysia, the Philippines, Timor-Leste, Papua New Guinea and the Solomon Islands. Indonesian coral reefs extent is estimated at 50,200km^2 including barrier reefs, fringing reefs, as well as atolls and their associated lagoons [1]. More than 500 species of coral cover a total of 70% of coral reef habitat in the Indo-Pacific [2, 3]. Marine biodiversity is used and is structured by a range of habitats [4-6].

Habitat mapping on coral reef ecosystems in Indonesia has been carried out using very high-resolution satellite imagery data and can support policy makers [4–6]. In particular, local government and stakeholders have been applied scientific studies to develop marine ecotourism in several locations including Pangandaran Region, West Java Province [7], Pulau Jemur, Riau Province [8], Maligi Nature Reserve, West Sumatra Province [9], Waerole and Nusa Telu, Maluku Province [10], Lembar Bay, Lombok island [11], South Sulawesi [12], Mandalika Exclusive Economic Zone, Lombok island [13], Gili Matra Marine Tourism Park (GMMTP) [14],

* Corresponding author: eghb001@brin.go.id

Kuala Sempang, Bintan [15] and *Taman Wisata Perairan* (TWP) Gitanada (in this issue). Reviews regarding marine ecotourism studies at these locations can be seen in Table 1.

Table 1. Selected publications on marine ecotourism in Indonesia

Reference	Location	Objective	Method
A. Nurhayati et al. (2019)	Pangandaran Region	Marine ecotourism (sustainability)	Multi-Dimensional Scaling
I. Effendi et al. (2019)	Pulau Jemur	Marine ecotourism object	In situ observation
L. Zamzami et al. (2021)	Maligi Nature Reserve	Marine ecotourism (coral reef fish)	In situ measurement
A.J. Ely et al. (2021)	Waerole and Nusa Telu	Marine ecotourism (development)	Qualitative model
Sukuryadi et al. (2021)	Lembar Bay	Mangrove ecosystem for ecotourism	Respondents (local community and stakeholders)
A. Tuwo et al. (2021)	South Sulawesi	Marine ecotourism (potential & problems)	SWOT analysis
L. Zulkifli et al. (2021)	Mandalika EEZ	Ecotourism (macrofauna diversity-seagrass)	Ecological and respondents
R.F. Rahmadyani et al. (2022)	Gili Matra Marine Tourism Park (GMMTP)	Valuation of services in coral reef ecosystem	Desk study and respondents
Gusrizal et al. (2023)	Kuala Sempang	Marine ecotourism (sustainability)	Quantitative and qualitative (RAB global)
E.E. Ampou et al. (2023)	Sumberkima, Bali	Marine ecotourism (Nudibranch)	Visual census
E.E. Ampou et al. (Current study)	TWP Gitanada	Marine ecotourism (coral reef)	Habitat mapping

The term ‘ecotourism’ describes a type of tourism which strives to be more socially and environmentally sustainable than ‘standard’ tourism [28, 29]. Tourism that is managed with the aim of minimising ecological impacts and promoting restoration may be considered ‘eco’, however, there is no universal agreement of the what constitutes ‘ecotourism’ [29] and consequently providers may convey false and/or misleading information about the environmentally friendliness of the product or service they offer.

Ecotourism is theoretically one of the most environmentally sound tourism activities, by prioritizing aspects of nature conservation, aspects of socio-cultural economic empowerment of local communities as well as aspects of learning and education, to raise the level of locally qualified management [14, 16].

This study aims first to classify coral reef habitat within the coral reef ecosystem of TWP Gitanada region, thus the provided information will be useful to guide ecotourism development in this area, by providing a baseline of the habitat richness on the study site. The results are presented in an easy-to-understand *graphical information format which targets the general public* with various demographic profiles.

Materials and Methods

Research sites

Based on the *Nusa Tenggara Barat* (NTB) Governor's Decree No. 523.1-972 year 2016, the TWP Gitanada in West Lombok region is included in the Management and Zoning Plan for Marine, Coastal and Small Islands Protected Areas of NTB Province. The research location is centered at 8°43’20" S 116°2’30” E (Fig. 1).

Data collection

Fieldwork was conducted in the aquatic tourism park called *Taman Wisata Perairan* (TWP) Gitanada, Sekotong, Lombok Barat in June 2021, which is a tourist destination on Lombok Island, NTB Province (Fig. 1).

In situ observations include systematic photographs, at least one per minute, using an underwater camera Olympus TG-7 with housing (if possible, fitted with a wide angle) and when the surveyor changes habitats. Photo interpretation of habitats based on these photographs is done using the [5] with Medium Scale Approached (MSA) [17, 18]. To link with satellite image data, it is necessary to mark the positions of the observations and record its continuous tracks with a GPS (Global Positioning System), to identify the exact areas that have been observed. Representative photographs were analyzed visually using a PC/laptop to estimate benthic coverage (semi-quantitative), rugosity, growth form and dominant species. These methods are frequently used in similar habitat mapping projects [19, 20].

Satellite imagery data (Sentinel 2A) acquired on May 12th, 2020. Downloaded from Copernicus Open Access Hub: *https://scihub.copernicus.eu/*

Graphical habitat description for the public (poster) which is made based on own creations by using a graphic design program tool.

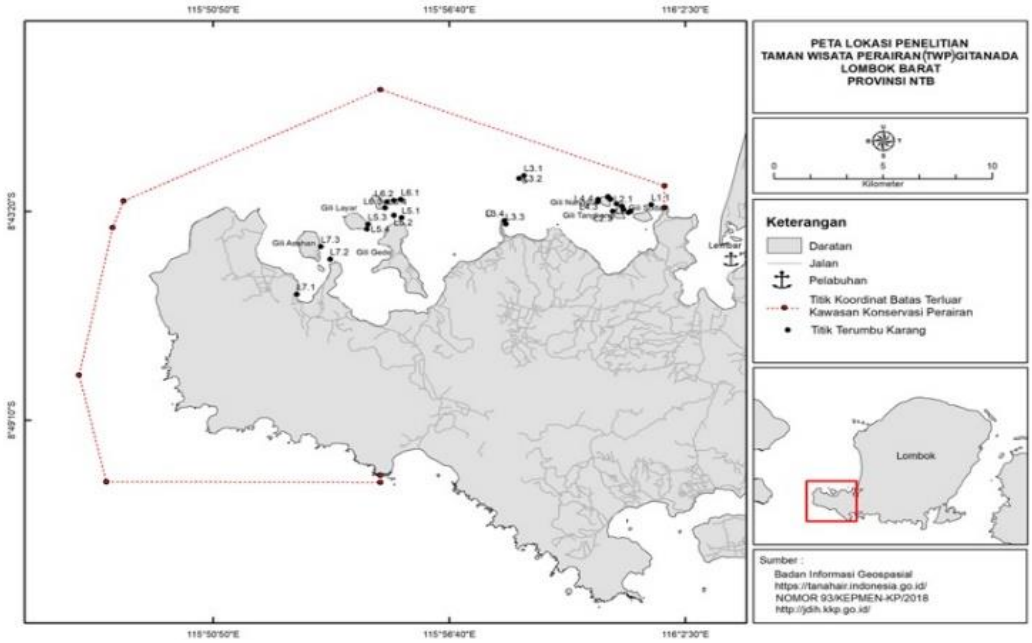

Fig. 1. The boundary of TWP Gitanada and location of survey stations for local habitat typology observation

Results and discussions

The total area of coral reef coverage in TWP Gitanada based on the Sentinel 2A image analysis is nearly 450 hectares (ha). The map consists of fringing reefs with a habitat typology: reef flat, fore reef/reef crest, reef slope, reef wall and patch reef (Figs. 1 and 2). Finally, in situ observations suggest that there are more than 200 types of coral reef habitats.

Habitats of Gili Sudak, Gili Tangkong and Gili Nanggu

Based on Sentinel 2A image analysis, the surface area of coral reefs in Gili Sudak, Tangkong and Nanggu is 79.3ha; while non-coral reefs cover 54.3ha. Typology of coral reef habitat in Gili Sudak, Tangkong and Nanggu can be seen in Figures 2 and 3. Representative characteristics of the habitat on the reef flat, reef slope and front reef are dominated by hard corals/*Scleractinia* including those from the genera *Acropora, Porites, Montipora, Diploastrea, Favites, Pocillopora* and *Seriatopora*. While soft corals are dominated by the genus Nephthea sp.

The substrate is generally rubble, sand and mud. Rugosity habitat average is ranging from level 2 to 4.

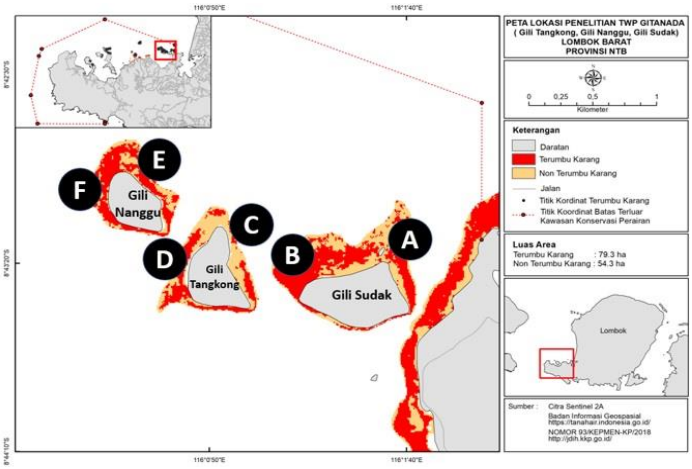

Fig. 2. The map of coral reefs in the Gili Sudak, Gili Tangkong and Gili Nanggu, which are grouped into six clusters. The characteristics of each habitat (from A to F cluster) are available in Figure 3.

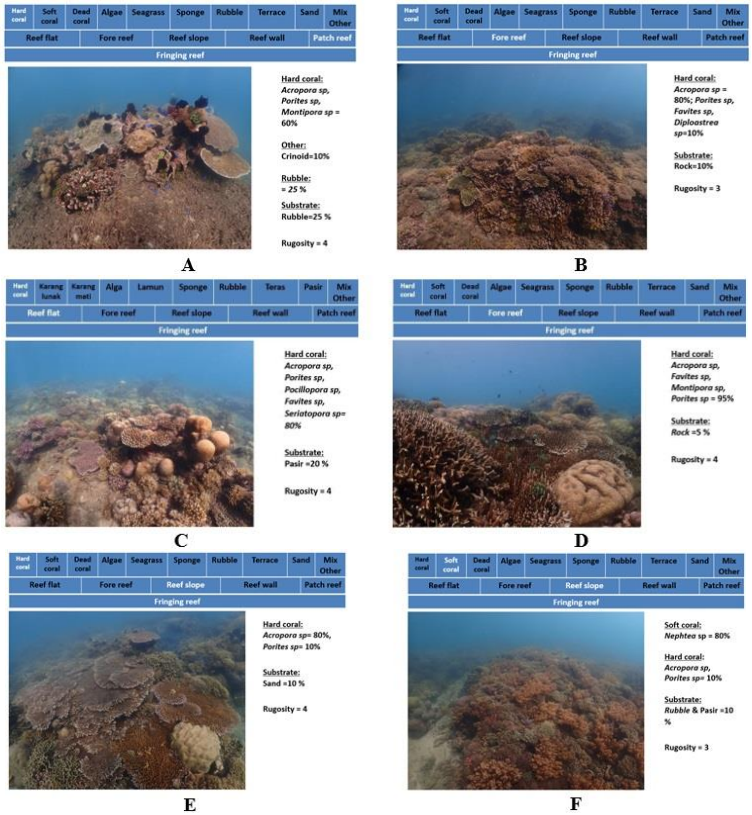

Fig. 3. Coral reef habitat representatives (A-F) of Gili Sudak, Gili Tangkong and Gili Nanggu

Habitats of Gili Poh and Elak-Elak

The surface area of coral reefs in Gili Poh and Elak-Elak is 80.8ha; while non-coral reefs cover 86.9ha. Typology of coral reef habitat in Gili Poh and Elak-Elak can be seen in Figures 4 and 5. Representative characteristics of the habitat on reef slopes, reef flats and front reefs are dominated by hard corals/*Scleractinia* including those from the genus *Seriatopora sp, Fungia sp, Acropora sp, Pocillopora sp* and *Montipora sp*. While the other category is dominated by the substrate is generally rock, rubble and sand. Average Rugosity habitat ranges from level 1 to 3. Based on analysis of Sentinel 2A image, the area of coral reefs in this area (Gili Gede, Takad Anyaran, Gili Rengit, Gili Layar, Gili Asahan and Tenggolong) is 288.8ha; while non-coral reef covers 272.4ha. The typology of coral reef habitats in Gili Gede, Takad Anyaran, Gili Rengit, Gili Layar, Gili Asahan and Tenggolong can be seen comprehensively in Figure 6 and 7.

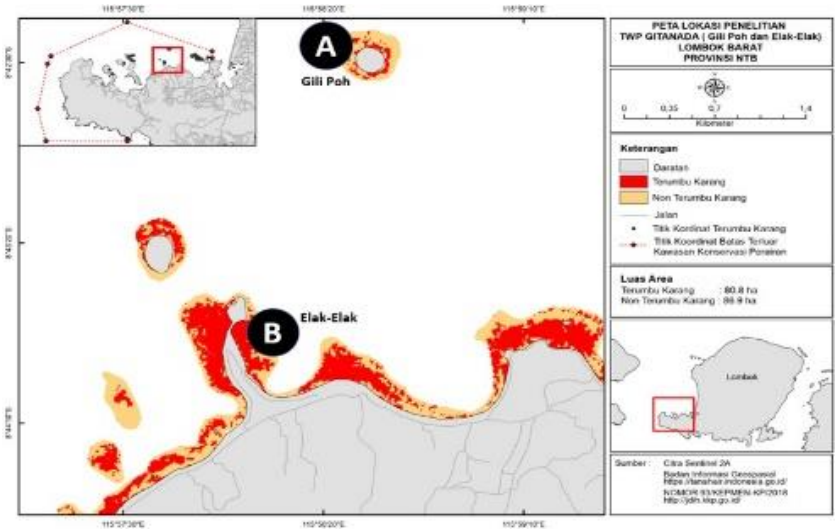

Fig. 4. Map of coral reefs in Gili Poh and Elak-Elak waters which are grouped into two clusters, while characteristics of habitats A and B are presented in figure 5.

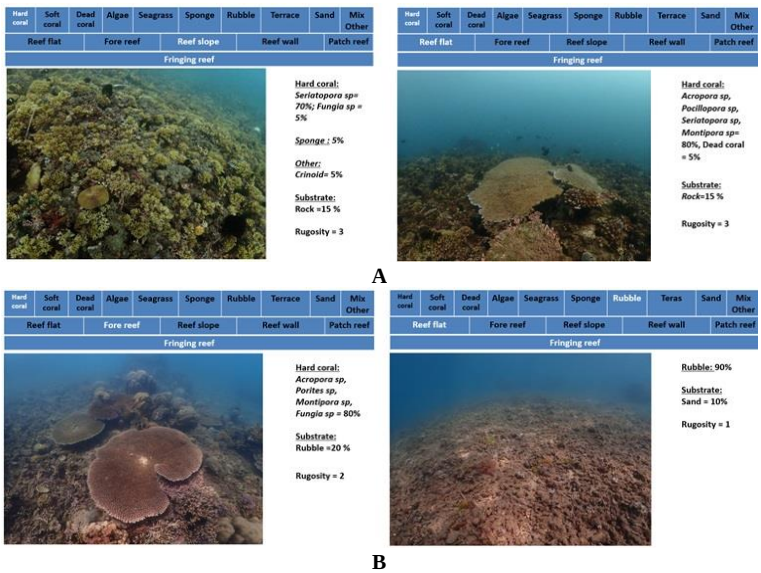

Fig. 5. Representative coral reef habitat A). Gili Poh and B). Elak-Elak.

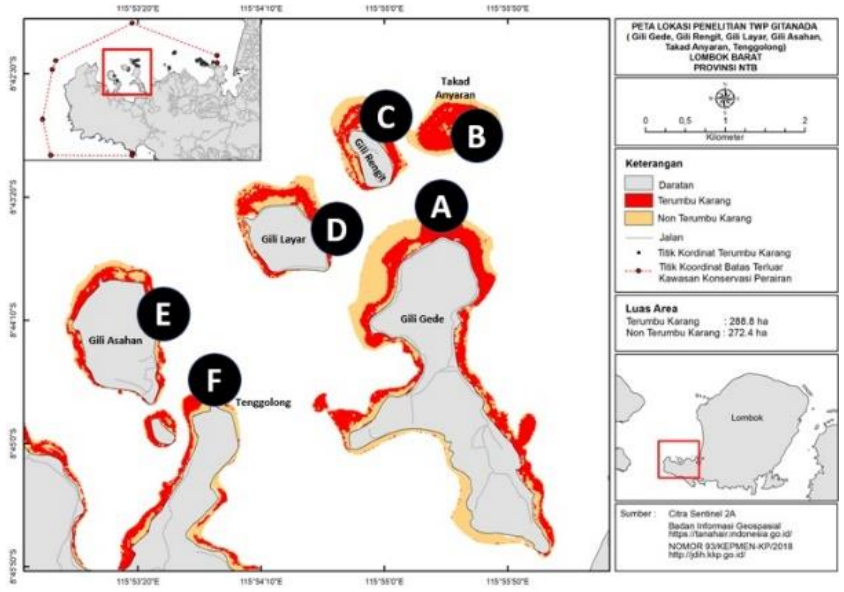

Fig. 6. Coral reefs map on: (A) Gili Gede; (B) Takad Anyaran; (C) Gili Rengit; (D) Gili Layar; (E) Gili Asahan; (F) Tenggolong

Representative habitat characteristics on the reef flat, front reef, reef slopes and more diverse strata are dominated by hard corals/*Scleractinia* including from the genera *Acropora sp*, *Acropora palifera*, *Diploastrea sp*, *Montipora sp*, *Porites sp*, *Favites sp*, *Hydnopora sp*, *Pocillopora sp*, *Seriatopora sp*; Non-*Scleractinian* corals from the genus *Millepora sp; Octocorallia* from the genus *Gorgonia sp*, *Nephtea sp*, *Xenia sp*; *Hexacorallia* of the order *Anthipataria*; Various types of Crinoid and Sponge; Algae of the type Sargassum sp. Even from other categories which includes a mixed variation of *Sclearctinia/non Scleractinia* corals, *Ocotocarallia*, *Hexacorallia* and algae. The substrate is generally stone, rubble, sand and terraces. Rugosity habitat average is ranging from level 2 to 4.

Synthesis of habitat observations

In June 2013, a monitoring activity was conducted by the Wildlife Conservation Society team, resulting in a general condition of coral reefs in the West Lombok waters which is now included in the TWP Gitanada area. This study revealed that coral reefs in this area are dominated and pioneered by the genus of *Acropora* and *Porites*. Particularly for the genus of *Acropora*, it has a significant growth process, but relatively low resistance compared to other types of corals [21]. Then, additional fieldwork was conducted in 2018, which showed an insignificant coverage expansion, from 35.52% in 2013, to 37.23% in 2018 [22]. The next observation was conducted in 2021, where the result indicated a similar result as 2018.

According to *N. Buhari et al.* [23] coral reefs (especially surrounding the Gili Gede) have a poor status with the average value of 21.92%. It is in line with the results of this study which showed that the dominant habitat at the same location is algae of the *Sargassum sp* 70% and category 'mix others' at 90% (Figure 7A) and rubble is dominant at 80% (Fig. 7F-left).

According to *I. Bachtiar et al.* [24], the condition of the coral reefs in Sekotong bay showed a significant decline, especially in the period of 2015-2017 which would affect the productivity of the reef fish population. This decline was followed by a decrease in coral reef index value, but then it experienced a recovery in 2018 [25, 26].

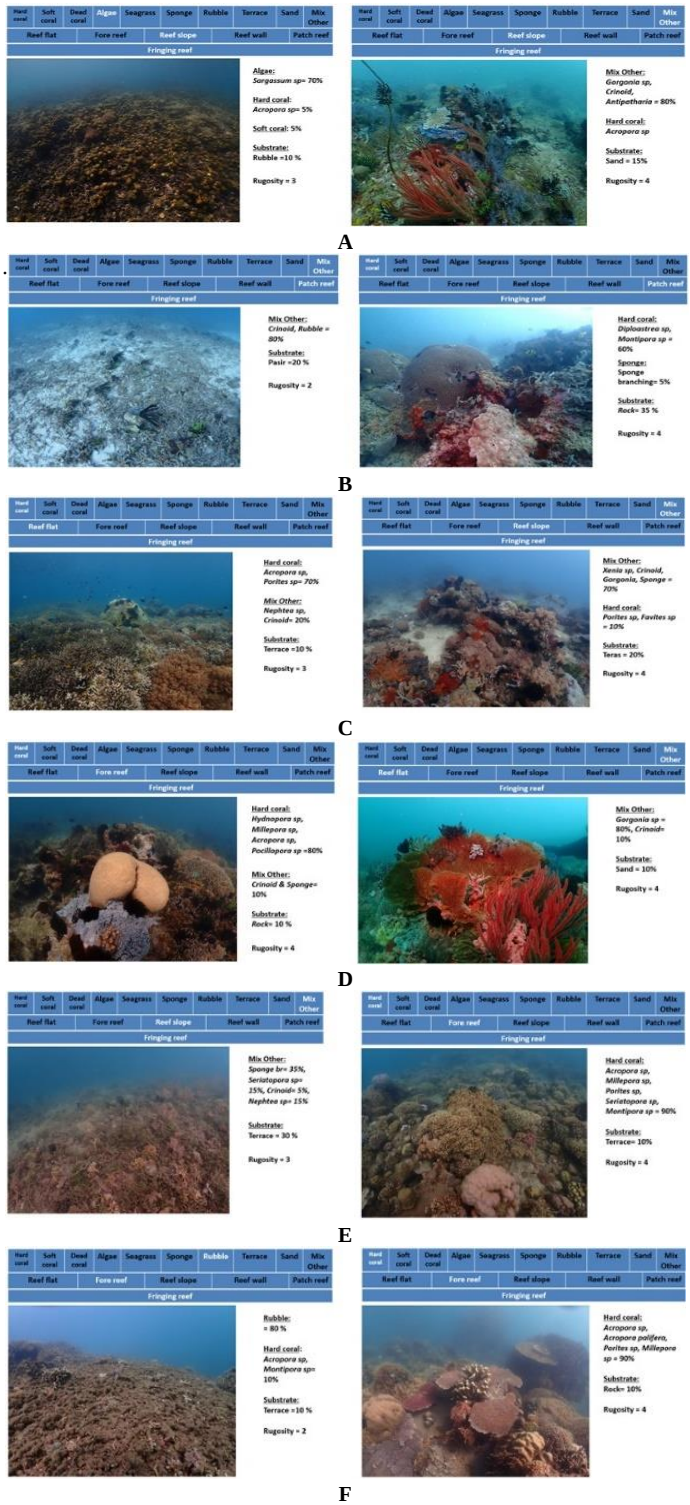

Fig. 7. Representative coral reef habitat: (A-F) Gili Gede; Takad Anyaran; Gili Rengit; Gili Layar; Gili Asahan; Tenggolong; with trajectories geomorphology of coral reef habitat

Comprehensive assessment of habitat diversity, which is presented here, should also be accessible to the general public and related stakeholders, especially in the areas that are dedicated to ecotourism. For this purpose, we provide an example of all representative data that has been acquired from this study, into a printed poster format (Fig. 8), or its digital format can also be uploaded to a related stakeholder's website. Potential visitors can download this poster to access additional information about coral reef habitat on this site etc. (Fig. 8).

Fig. 8. An example of an attractive infographic poster to support ecotourism in a conservation area (especially dedicated for domestic tourists). This poster can be displayed in related tour and travel agencies, or distributed to other stakeholders, including tourism business outlets around TWP Gitanada. By increasing general knowledge regarding the area, it could generate tourists' interest in visiting this site

Conclusions

The coral reef area in TWP Gitanada covers 450ha with the diversity of more than 200 types of coral reef habitat, dominated by *Scleractinian* corals of the genus: *Acropora*, *Montipora*, *Porites* and their associations (mix others). These scientific data and information regarding coral reef habitat should also be presented to the public in the form of infographics posters, thus generating interest in visiting the TWP Gitanada particularly, or other marine conservation areas and marine conservation candidates throughout Indonesia in general (to maintain the sustainability of ecotourism business). The data and information from this study can also be used to determine which zones of Gitanada areas need to be treated for conservation, maintained and for other potential uses by relevant stakeholders.

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