Implementation of coral propagation for coral reef garden in Nusa Dua, Bali

E E Ampou¹, P Hutasoit², N Janetski³, S Yusuf⁴, A Damar⁵, C Petta⁶, A A Hutahaean⁷

¹Institute for Marine Research and Observation, Ministry of Marine Affairs and Fisheries (MMAF), Bali
²Nusa Dua Reef Foundation, Bali
³Marine Sustainability Program, Indonesia
⁴Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar
⁵Faculty of Fisheries and Marine Science, Udayana University, Bali
⁶Center for Management of Coastal and Marine Resources, MMAF, Bali
⁷Coordinating Ministry of Maritime Affairs, Jakarta

Email: eghbert.ampou@kkp.go.id

Abstract. MARRS (Mars Assisted Reef Restoration System) is an artificial reef method that resembles spider webs and has been implemented in several regions of Indonesia, including Samuh beach, Nusa Dua, Bali. Since July - October 2018, 761 MARRS units, supporting a total of ± 10,600 coral fragments, have been installed. The aim of this research is to provide an initial investigation into establishing a mini-coral reef park in Indonesia. Monitoring was done by identifying habitat geomorphology methods with photo transects and coral propagation status in MARRS using the random visual census method. From the process of habitat geomorphology classification in the artificial reef network, there were 9 types of habitat classified on the fringing reef, reef flats and fore reefs. Ten hard coral species from the Scleractinia group were identified from 10 randomly-selected and monitored MARRS units: Acropora formosa, A. hyacinthus, Pocillopora verucosa, P. damicornis, Psammocora sp., Symphyllia sp., Stylophora pistillata, Turbinaria sp., Echinopora sp. and Favites sp. Three significant coral factors were found to be present within the coral propagation system: resistance, competition and predators.

1. Introduction
Geographically, Indonesia has an extensive coastline spanning 95,181 km, with existing conditions for coral reefs covering 50,000 km² [1,2]. Coastal ecosystems across the country may be natural or man-made. Natural ecosystems found in coastal areas include coral reefs, mangrove forests, seagrass beds, sandy beaches, rocky beaches, pescapræ formations, barringtonia formations, estuaries, lagoons, deltas and small island ecosystems [3,4]. Indonesia, as part of the so-called Coral Triangle, is the biodiversity epicentre for corals in the world., with over 600 species [5]. Geomorphologically, benthic habitats found in coral ecosystems include sediment deposits (e.g. sand and mud), mangroves, submerged vegetation (e.g. seagrass and algae), hermatypic coral reefs and colonized hard base habitats spurs and grooves, patch reef, pavement, gorgonian and bedrock) and other hard substrates (e.g., rubble and non-layered rocks). Typical structural zones include fore reefs, reef flats and lagoons [6]. In general, habitats can be defined as spatial and functional entities characterized by various
biological and abiotic parameters, at certain spatial scales that depend on the context [7]. For habitat mapping using remote sensing, habitats are described by four types of variables, which refer respectively to the geomorphology, architecture, cover and taxonomy of the dominant structural species in the area, which may cover anywhere between several square meters and several thousand square meter [8,9].

Artificial reefs, an example of man-made ecosystems, depend on long-term processes and take approximately 20 years for some coral fragments to form mature colonies and to develop the complex symbiosis with reef fish and other organisms found in natural reefs. Following these processes, they may be referred to as artificial coral reefs [10,11]. Since 2008 – 2013 the MARRS project has collaborated with local communities to establish a major programme for the rehabilitation of coral reefs promoting the sustainability of fisheries resources and community livelihoods [12]. This artificial reef programme has since been developed in several regions across Indonesia.

This paper presents a preliminary investigation of the man-made mini coral reef park areas in Indonesia, providing geomorphological habitat classification and random coral propagation visual census on the reefs made by MARRS.

2. Material and Methods

2.1. Study site
This research was conducted in August 2018 for habitat geomorphology classification and February 2019 for coral propagation status, in Samuh beach, Nusa Dua, Bali (115°13'-115°14' E and 8°47'30-8°47'47 S), which is one of the tourism areas in Bali Province.
2.2. Data collection

2.2.1. Geomorphological habitat. Field data collection (Figure 2), was undertaken with a medium-scale approach technique (Medium Scale Approach MSA) [13]. A 5x5m square was estimated and benthic cover within that area was recorded [14], followed by divers calculating the Semi Quantitative Scale benthic habitat (SQS): 0 (0%), 1 (1–10%), 2 (11–30%), 3 (31–50%), 4 (51–75%) and 5 (76–100%) along with the relatively easy identification of habitats >25m [13,15]. In general, this method was carried out in situ, although it is also possible to use photo transects [16]. This technique has also been applied [17–19], alongside experienced coral reef ecosystem experts (surveyors) proven to be able to quickly complete 6-8 transects a day in the reef flat area.

2.2.2. Visual census. The process of coral propagation data collection on MARRS-made reef structures was carried out by visual census using random sampling on SCUBA diving equipment, with underwater cameras, pencils and slates [14,20] and tagging in the form of cable ties on each artificial reef monitored. This activity was undertaken to facilitate further monitoring activities.

2.2.3. Data Analysis. Field data in the form of photographs of collected coral habitat transects was compiled and analysed visually by using computers to assess the area of cover (semi-quantitative) [13], rugosity, growth forms and dominant species [8,9]. To measure rugosity, a categorical scale of 0 - 5 was employed to represent the level of variation in amplitude of the surface height – in this case, the habitat of the coral reef ecosystem. Growth form was categorized using habitat classification, while the dominant species provided examples of habitats dominated by a particular type of coral [8]. Coral propagation was analysed using descriptive statistics.

3. Results and Discussion
Since July - October 2018 there have been 761 MARRS units installed, with a total of ± 10,600 coral fragments dominated by Scleractinian corals (Figure 2).

3.1. MARRS Status
The monitoring activity was carried out on the reef slope at a depth of 7-10 m. Random monitoring method was employed using underwater cameras [14,20]. Out of a total of 500 reef spider units deployed in October 2018, 10 units were randomly sampled over 2 dives (dive 1 = 7 RS units; dive 2 = 3 RS units). A total of 10 hard coral species from the Scleractinia group were identified, consisting of the following species: Acropora formosa, A. hyacinthus, Pocillopora verrucosa, P. damicornis,
Psammocora sp., Symphyllia sp., Stylophora pistillata, Turbinaria sp., Echinopora sp. and Favites sp. The status of the respective species was also recorded (Figure 3).

The percentages of each coral genus on the MARRS units are shown in Figure 4. There were 3 significant categories found on MARRS:

- Resistant: corals were able to acclimate to changes in the surrounding environment
• Competition: corals were invaded by other organisms (e.g. CA & Cyanobacteria), thus affecting the growth process.
• Predators: corals were preayed-upon by other predators (e.g. parrot fish bite, Crown of Thorn Starfish, Drupella sp., etc.).

On M-7 ten coral species were dominantly resistant = category 1. While on M-1 to M 6 there were six types of coral with the following categories: M-1 = category 2 & 3; M-2 = categories 1 & 3; M-3 = categories 1 & 2 with a small percentage experiencing death, especially from branching corals of the genus Acropora; M-4 = categories 1 & 2; M-5 = categories 1,2 & 3; M-6 = categories 1 & 2.

**Figure 4.** Percentage of coral genera in MARRS.

3.2. Geomorphology habitat classification

Based on habitat representation using typology identification cards [19], the ecosystem around the coral transplantation site consisted of 9 habitat types, classified as fringing reef with reef flat and fore reef types. (Figure 5).
Figure 5. Nine habitat types of geomorphology identification on Samuh beach.

Based on observations using visual census [14,20], geomorphologically the Samuh coastal area, especially the location where coral transplantation activities was planned, was classified as a fringing reef with formations of spurs and grooves. Two typologies represented were reef flats and fore reefs. Based on the classification of habitat, hard coral (Scleractinian) habitat ranged from 40-60% and soft corals ±60% with the dominant types being Sarcophyton sp. and Xenia sp. On average, the reef flat area was dominated by seagrass beds of the type Enhalus acoroides, Syringodium sp. and Thallasodendron sp.

For these reasons, it is highly recommended to follow up this study with: (1) routine monitoring activities related to coral status and their associations on MARRS every 2 - 6 months; (2) cleaning at least once every 3 months; (3) water quality samples, at least representing the seasonal variation (needed to find out the standards of seawater quality around the location of MARRS); (4) scientific studies of growth, health, disease, ocean current modelling and other related matters that are needed as supporting data, especially in the area of artificial reefs and its surroundings (integrated study/research) with relevant stakeholders.

Acknowledgements.
This study was made possible by the support of the Coordinating Ministry of Maritime Affairs with Nusa Dua Reef Foundation for the side event “Replanting Coral IMF-WBG Annual Meeting 2018”. The paper benefited from discussion with Frida Sidik and I Nyoman Radiarta.
References
[1] NOAA 2016 Global Maritime Boundaries Database World Vector Shoreline US Def. Mapp. Agency
[2] Ampou E E, Radiarta I N, Hanintyo R and Andréfouët S 2018 Mapping of Benthic Habitats on Coral Reef Ecosystem in Menjangan Island J. Kelaut. Nas 13
[3] Dahuri R 2013 Keanekegaragaman Hayati Laut aset pembangunan berkelanjutan Indonesia (Jakarta: Gramedia Pustaka Utama)
[4] Ampou E E and Yusuf C H 2009 Inventarisasi Benthic Life Form dan Aplikasi Marxan di GiliLawang-Gili Sulat, lombok Timur Program Rehabilitasi dan Pengelolaan Terumbu Karang pp 85–91
[5] Veron J E N, Devantier L, Turak E, Green A, Kininmonth S, Stafford-Smith M and Peterson N 2009 Delineating the Coral Triangle Galaxea J. Coral Reef Stud. 11 91–100
[6] Rohmann S O, Hayes J J, Newhall R C, Monaco M E and Grigg R W 2005 The area of potential shallow-water tropical and subtropical coral ecosystems in the United States Coral Reefs 24 370–383
[7] Galparsoro I, Connor D W, Borja A, Aish A, Amorim P, Bajjouk T, Chambers C, Coggan R, Dirberg G, Lillis H, Evans D, Goodin K L, Grehan A J, Haldin J, Howell K L, Jenkins C, Michez N, Mo G, Buhl-Mortensen P, Pearce B, Populus J, Salomidi M, Sánchez F, Serrano A, Shumchenia E J, Tempera F and Vasquez M 2012 Using EUNIS habitat classification for benthic mapping in European seas: Present concerns and future needs Mar. Pollut. Bull. 64 2630–2638
[8] Andréfouët S 2014 Fiches d’identification des habitats récif-lagonaires de Nouvelle-Calédonie Notes techniques ed IRD (Nouméa)
[9] Andréfouët S 2016 Contribution à l’étude de la biocomplexité des récifs coralliens de l’Indo-Pacifique : le cas des atolls (Institut de Recherche Pour le Développement)
[10] White A T, Ming C L, De Silva M W R N and Guarin L Y 1990 Artificial Reefs for Marine Habitat Enhancement of Southeast Asia. (ICLARM Educ)
[11] Edrus I N, Wiadnyana N N and Suharsono 2018 Pembuatan dan Penempatan Terumbu Buatan Rehabilitasi Ekosistem Terumbu Karang Untuk Keberlanjutan Sumberdaya Perikanan (-Badan Riset dan Sumberdaya Manusia Kelautan dan Perikanan, Jakarta, Indonesia: Amafrad Press) pp 1–20
[12] Williams S L, Sur C, Janetski N, Hollarsmith J, Rapi S, Barron L, Heatwole S J, Yusuf A M, Yusuf S, Jompa J and Mars F 2019 Large-scale coral reef rehabilitation after blast fishing in Indonesia: Coral reef rehabilitation Restor. Ecol 27 447–456
[13] Clua E, Legendre P, Vigliola L, Magron F, Kulbicki M, Sarramegna S, Labrosse P and Galzin R 2006 Medium scale approach (MSA) for improved assessment of coral reef fish habitat J. Exp. Mar. Biol. Ecol 333 219–230
[14] English S, Wilkinson C and Baker V 1997 Survey Manual for Tropical Marine Resources Australia Marine Science Project, Living Coastal Resources, Australian Institute of Marine Science (Townsville, Australia: ASEAN)
[15] Dahl A L 1981 Coral reef monitoring handbook (Noumea, New Caledonia)
[16] Andréfouët S 2008 Coral reef habitat mapping using remote sensing: A user vs producer perspective. implications for research, management and capacity building J. Spat. Sci. 53 113–129
[17] Scopélitis J, Andréfouët S, Phinn S, Chabanet P, Naim O, Tourrand C and Done T 2009 Changes of coral communities over 35 years: Integrating in situ and remote-sensing data on Saint-Leu Reef (la Réunion, Indian Ocean) Estuar. Coast. Shelf Sci 84 342–352
[18] Ampou E E 2016 Caractérisation de la résilience des communautés benthiques récifales par analyse d’images à très haute résolution multi-sources : le cas du parc national de Bunaken, Indonésie (Université Toulouse III Paul Sabatier, France)
[19] Ampou E E, Ouillon S and Andréfouët S 2018 Challenges in rendering Coral Triangle habitat
richness in remotely sensed habitat maps: The case of Bunaken Island (Indonesia) *Mar. Pollut. Bull* **131** 72–82

[20] Bianchi C N, Pronzato R, Cattaneo-Vietti R, Benedetti-Ceccchi L, Morri C, Pansini M, Chemello R, Milazzo M, Fraschetti S and Terlizzi A 2004 Hard Bottoms *Biol Mar Medit* **11** 185–215

[21] Ampou E E, Hutasoit P and Hutahaean A 2018 Transplantasi Karang di Nusa Dua Berharap Jadi Taman Terumbu Karang Indonesia