(8)

PAPER • OPEN ACCESS

Potential Uses of Genetic Studies for MPA Design

To cite this article: W Umar *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **253** 012032

Potential Uses of Genetic Studies for MPA Design

W Umar[1], A C M A R Tassakka[1] and J Jompa[2]

[1]Faculty of Marine Science and Fisheries, Universitas Hasanuddin, Indonesia
[2]Marine Resilience and Sustainable Development Centre of Excellence, Universitas Hasanuddin, Indonesia

Email: widyastuti160@gmail.com

Abstract. In recent years, coral reef degradation has been increasing. Management and conservation efforts have tended to focus only on the physical condition of the coral reefs with less attention to biological and oceanographic aspects, in particular genetics and hydrodynamics. Genetic data can illustrate the connectivity between and within populations of an organism, making it is possible to determine source and sink populations or sites. Studies of physical water movements can also illustrate the likely patterns of movement or predict the mobility of coral planulae. Both of these approaches can help to strengthen Marine Protected Area (MPA) design, especially at the formation stage, in particular MPAs focused on coral reef ecosystems. Together, these two approaches can provide data on biological networks in a region and help delineate stocks. The implications of such studies can help to identify conservation priorities and improve the effectiveness of management processes in Indonesia, and can certainly enable the refinement of general approaches to help produce management plans tailored to local and regional conditions and processes. This brief review aims to review the constraints that occur in the management process, including barriers to and potential benefits of integrating molecular and hydrodynamic data into the management and conservation process, as illustrated through a critical review of MPA implementation in the waters around Sulawesi Island.

1. Introduction

It is perhaps not surprising that our oceans are currently considered under threat. The global human population has increased exponentially to around 7 billion and is still growing. One significant result of this increase is an ongoing rise in the already high demand for marine resources, which is growing by over 3% every year [1]. The growing human population is exacerbating the uncontrolled exploitation of aquatic resources [2], including impacts on the condition of coral reefs, many of which are found in the areas most intensively touched by human activities such as capture fisheries and tourism [3]. One management instrument increasingly used at local, national, regional and global levels is to establish conservation areas in the marine environment, generally referred to generically as marine protected areas (MPAs). An effective marine protected area (MPA) or marine protected area network should be able to sustain marine resources within its boundaries, and contribute to the replenishment of surrounding waters [4].

According to the terminology used in Regulation of the Minister of Maritime Affairs and Fisheries Number Per.30/MEN/2010, in Indonesia an MPA is an area which is "protected and managed with a zoning system to realize the sustainable management of fisheries resources and the environment". Therefore, in determining an MPA, there are many important aspects that need to be taken into account, including ecological, social, regional, economic and pragmatic aspects. From an ecological point of view, key factors in the determination of location include biodiversity, representativeness, productivity, uniqueness, the biology of marine organisms and connectivity. However knowledge and information on these biological and ecological factors is often missing, making it difficult to apply an effective and coherent approach to MPA site selection and subsequent management.

In this context, genetic approaches could potentially make an important contribution in determining the design of marine conservation areas. Population genetics and connectivity are very important, and indeed basic, aspects of understanding the current physical and biology conditions and the likely responses of a system to change [4,5,6] even though, in fact, they are often ignored in process of designing a new conservation area. Many benefits can be reaped from the application of genetic (molecular biology) methods, including in the investigation of environmental change that affects adaptation patterns of organisms and their resilience, and in determining important relationships between organisms and populations from different, and some times far distant, locations [5]. Several studies illustrate the important role of genetic methods in the management of two Carribean coral species, Acropora cervicornis [7] and Acropora palmata [8], both of which are listed as endangered and protected species in the United States. The geographical scale at which theses corals are managed needs to be considered in regional conservation planning, because the genetic flow within sub-regions tends to be limited, with little opportunity of larval export to and import from surround areas [7,8]. Knowing such facts can help avoid mistakes in decision making.

When talking about the need to involve genetic methods in marine management, the molecular biology aspects can't be separated from the role of hydrodynamics. In the vast majority of marine organisms, during at least part of the life cycle (e.g. larva/planula phase in corals), mobility and thus survival, recruitment, and distribution, is very much affected by currents and other water movement. Coral with a pelagic life phase (larva/planula) of around 2-7 days [9.10] and 3 weeks [11] will be strongly affected by oceanographic conditions, in terms of survival and the areas in which they might have a opportunity to settle and grow. The role of water flow is not only important for the distribution of coral planulae, but also to bring oxygen, warm water, and other resources needed for coral growth [11]. Improving our understanding of the interplay between currents and other factors in the distribution and recruitment of coral planulae will provide generic information of value in supporting MPA design and management [12,13].

Sulawesi and its satellite archipelagos are highly complex from a geological pointof view, and form a region of outstanding marine biodiversity potential [14,15], with a strategic geographical position in the center of Indonesia and the Indonesian Coral Triangle Area (ICTA). With its complex geography, circulation in the seas around Sulawesi is extremely complex and complicated, so that marine organisms can display unexpected and unique distributions and genetic population structures. This review will show how a molecular biology approach could play a role in the design of MPAs and MPA networks in the seas around Sulawasi, especially in site selection.

2. Method

This study collected data through a literature search. The data and information obtained were evaluated for validity and reliability and analysed descriptively. The analysis focussed on aspects relevant to the use of genetic studies in MPA design, with a special focus on applications to the seas around Sulawesi, and in particular the conservation of coral reef ecosystems in these waters.

3. Result and Discussion

3.1. Marine Protected Areas in Indonesia

The history of the establishment of marine protected areas in Indonesia began even before this country was colonized by the Netherlands. However, the criteria and implementation of protected sites was not as complex as now. At that time, certain marine areas were afforded varying levels of protection under customary activities. In early 2000, the FAO issued a warning to the nations of the world that, despite an ongoing increase in fishing effort, the total global marine fish production had begun to stagnate. As a country with a globally significant marine fish production, Indonesia is suffering from similar trends. Studies on the status of Indonesia's fisheries resources show that many stocks are in poor condition [16], with the majority in fully-exploited or over-exploited condition. If current trends continue, many coastal communities highly dependent on fishing will loose their main source of livelihoods. Many parties have come to consider conservation areas as an urgent need in order to stem this decline.

Conservation areas in Indonesia can be divided into 4 groups: (1) conservation areas established by the Ministry of Forestry (now the Ministry of the Environment and Forestry, MEF); (2) conservation areas established by the Ministry for Marine Affairs and Fisheries (MMAF); (3) conservation areas established by local governments (previously mostly at District level; since 2014 limited to the Provincial level); and (4) conservation areas established through the agreements at the local level (e.g. through village ordinances or customary systems). The Indonesian government, through the Ministry for Marine Affairs and Fisheries (MMAF), has established a set of criteria for the establishement of marine concervation areas (Permen Number 2/2009). This regulation sets out criteria based on three main aspects: ecological, social and cultural, and economic concerns. The ecological criteria include biological diversity, natural (unaltered/undegraded) state, ecological linkages, representativeness, uniqueness, productivity, landscapes/seascapes, rare fish habitat, fish spawning areas, and nursery areas. Social and cultural criteria include: community support, potential for conflicts of interest, potential threats, local wisdom and customs. Economic criteria include economically important fisheries, tourism potential and activities, aesthetics, and accessibility. There is a similar set of criteria, zonation systems and statutory regulations for a different suite of coastal and small island conservation area types which can be established under another MMAF regulation (Permen 17/2008). Both regulations can be used as a basis for gazetting national or provincial MPAs.

Indonesia had 76 marine conservation areas in 2016 (Figure 1), amouting to a total area of 19 millions ha, an increase from the 16 million ha achieved by 2012 [17]. These MPAs are distributed across the Indonesian Archipelago (Figure 2). The majority of these conservation areas were established under the provisions of Statute Number 45/2009 on Fisheries and use the nomenclature in Permen 2/2009, while the remainder were established under the provisions of Statute Number 27/ 2007 on the Management of Coastal Area and Small Islands and use the nomenclature in Permen 17/2008.

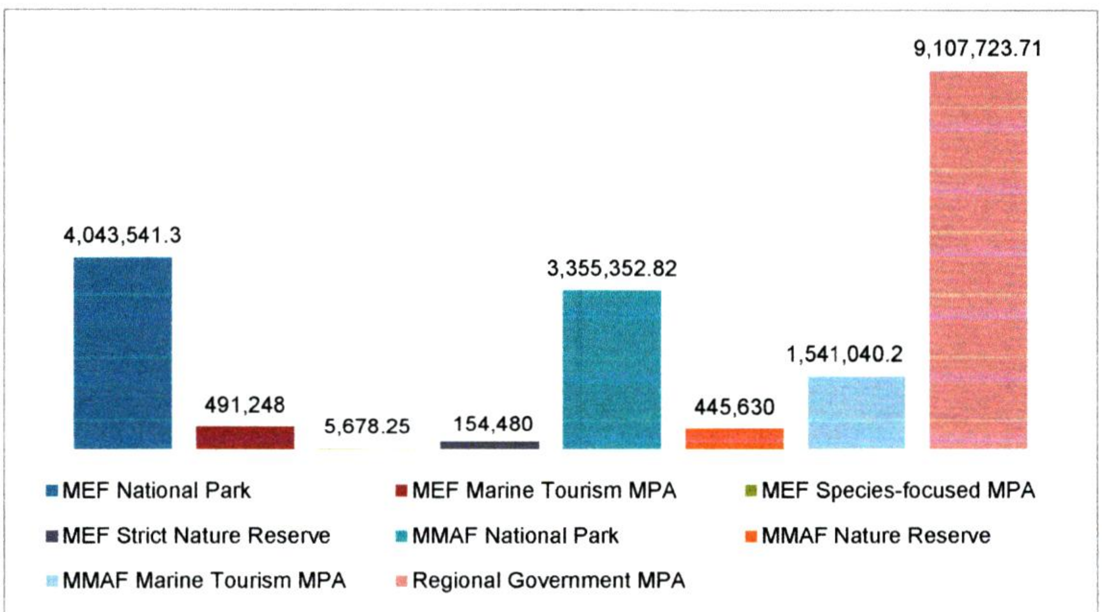

Figure 1. Conservation Areas in Indonesia in 2016.

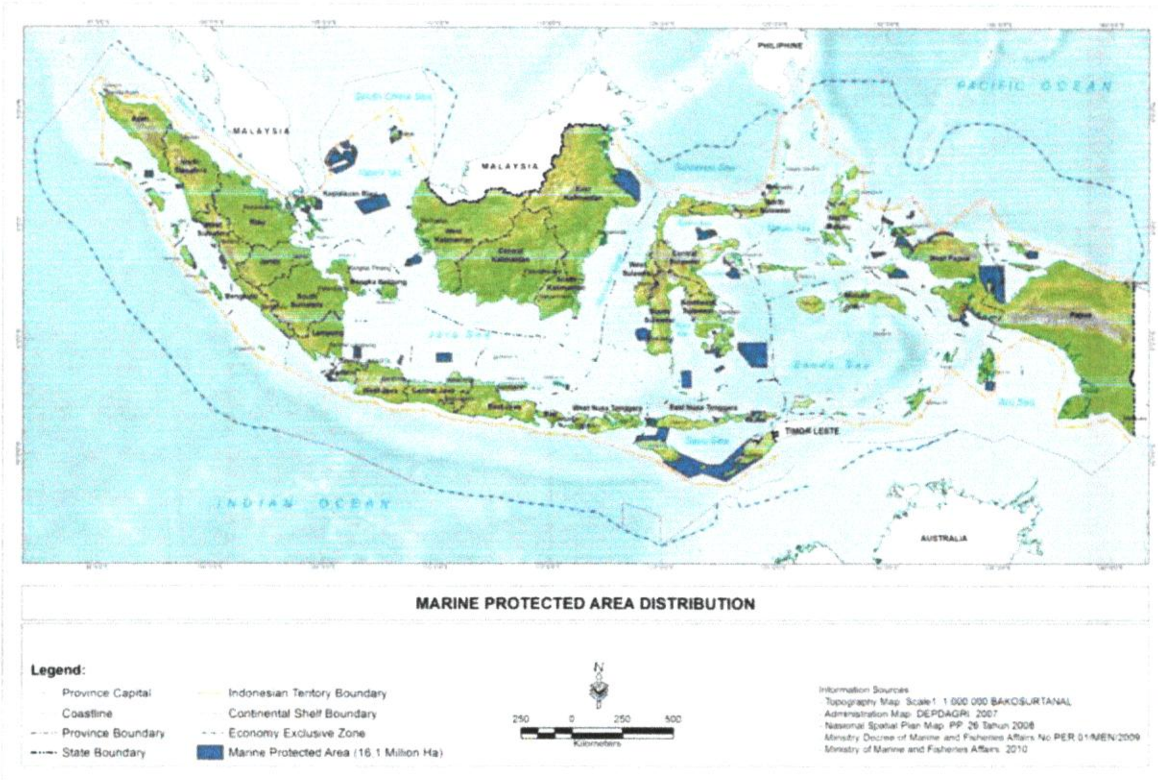

Figure 2. Distribution of Marine Protected Areas in Indonesia in 2012 [17]

In managing these established (gazetted) conservation areas, there are at least three major challenges that need to be addressed by government and all parties (stakeholders) involved. These are: how can MPA management become effective; how to ensure the allocation of sufficient funds for marine conservation from government or other sources on a regular (sustainable) basis; and how to resolve conflicts between vested interests and the many different sectors both inside and affecting the marine conservation area. These challenges have become pressing issues that have to be faced if the proverbial "paper park" syndrome is to be avoided, especially in view of the Indonesian Government plan to increase the area of MPAs to 20 million ha by 2020. It is relatively easy to gazette areas in order to achieve such a target quantitatively, but to succeed qualitatively (i.e. create and implement effective MPAs) is much greater challenge with a vastly higher level of complexity. The design of MPAs in Indonesia is still based on old systems with limited regard to the likelihood of successful implementation and effectiveness in achieving conservation targets. The pressure to meet national targets has tended to result in approaches which maximise MPA extent, and socio-political or oportunistic factors have often played a significant role. Meanwhile, the scientific basis has frequently been weak, and attention to biological principles and biogeographical factors has often been limited.

3.2. The Marine Protected Areas around Sulawesi

The condition of the current MPAs in Sulawesi (Table 1), as indeed across much of Indonesia, leaves much to be desired. According to the Indonesian criteria for MPA management effectiveness evaluation, most are in the Red category, being either not yet fully implemented or falling short of the relevant management targets. Field observations in several national MPAs indicate that implementation has often not followed policy guidelines, enabling innapropriate actions and failing to support the function and conservation targets of the conservation area. In some cases the large total area with inadequate involvement of stakeholders and often supported by inadequate resources, result in processes, outputs and outcomes which are far from ideal. Extensive and diverse coral reefs are found in the seas around Sulawesi and its satellite archipelagos, however very few are actually afforded any protection. In addition to the MPAs in Table 1, around 25 terrestrial conservation areas have marine components, but only a small proportion of the reefs in these conservation areas (or indeed in the MPAs) are actually protected in any meaningful way.

Table 1. Marine conservation areas in Sulawesi.

Province	National Park/ MPA	Marine Tourism Park	Regional Aquatic Conservation Area	Regional Coastal and Small Island Conservation Area	Marine Fisheries Reserve
South Sulawesi	• Taka Bone Rate	• Kapoposang	• Pangkajene and Tupabbiring Archipelago • North Luwu • Selayar	• Barru	
North Sulawesi	• Bunaken	• North Minehasa	• South Minehasa	• Bitung	
West Sulawesi			• Majene	• Polewali Mandar	
Southeast Sulawesi	• Wakatobi • Lasolo Bay	• Bombana • Padamarang Archipelago	• Southeast Sulawesi • Tiworo Strait • Buton		• Kolaka • Konawe
Central Sulawesi	• Togean Islands	• Libutan Sibitolu	• Tomini Bay; Morowali;	• Banggai Dalaka (gazetted in 2017)	
Gorontalo			• Boalemo; Pausuran, Olele		

The Statutes (UU45/2009 and UU 27/2007) on which MPA designation is based recognise three biodiversity levels (genetic, species, and ecosystem), all of which should be conserved or maintained. However, to date, the determination of conservation areas has paid little if any attention to the lowest level, genetic biodiversity, despite its importance in maintaining biological and ecological integrity. From a functional viewpoint, the investigation of genetic diversity can not only help to explain current distributions of an organism, but also identify source and sink areas, i.e. where the propagules of marine organisms originate from (e.g. crucial spawning sites) and where they tend to recruit (e.g. potential sites for sustainable fisheries), and identify special needs for the management of particular species or species groups [4,6,13]. Such information can support the processes involved in optimizing MPA network design and management.

Although there are 29 MPAs listed in Table 1, not one was established based on comprehensive genetic information, indeed in most cases no such data appear to have been used. Furthermore, although some such information is now available for a limited number of species or species groups within or across a few of these MPAs at a variety of scales (e.g. [18,19,20,21]), such data are often not in a format accessible to managers and other stakeholders, and have yet to be incorporated into MPA management. Meanwhile, for the vast majority of these MPAs relevant genetic structure and connectivity data to support management are not yet available.

The lack of data on genetic population structures and connectivity means that the spatial design of many MPAs, in terms of outer boundaries and zonation within the MPA, may far from ideal in terms of achieving conservation goals. For example, there might be a lack of knowledge regarding which areas need to be given maximum protection to prevent the rupture of vital links, and to maintain the sources and networks ensuring the distribution and recruitment of marine organisms within and outside the MPA.

3.3. Fine-scale patterns of scleractinian corals

Hard corals are aquatic organisms with a key role in tropical ecosystems, with distribution patterns that are strongly affected by water movement. There are broad biogeographical patterns affecting Indonesian coral reefs and the distribution of marine organisms, including corals [22,23,24]. The Indian Ocean currents affect coral reef distribution and coral dispersal along the coasts of west Sumatera and South Java. Diversity of corals on reefs in this area is relatively low because of the up-wellings bringing cooler deep ocean waters to the surface. The high rates of sedimentation along the north coast of Java have resulted in high turbidity and predominantly silty and muddy bottoms with relatively low coral diversity compared to other areas. The distribution of coral reefs along the east coast of Sumatera, West Borneo and South Borneo is also affected by high rates of sedimentation around river estuaries. The growth of coral reefs in Indonesia is often better developed around small islands which are separated from the main islands, with small or even no river estuaries, hard coastal structure and substrate, and often complex patterns of water flow including strong currents. Most such areas are in Eastern Indonesia, for example in the seas around Sulawesi, Maluku, East and West Nusa Tenggara, Bali, and Papua, where the branches of the Indonesian Throughflow (ITF) are thought to play a major role, while other important ocean current features include the Halmahera Eddy and the North and South Equatorial currents, as well as many local and seasonal currents.

Corals depend on the distribution of larval stages by ocean currents in order to colonize new reefs and replace coral lost through natural mortality as well as anthropogenic impacts [10,11]. Thus, larval dispersal and settlement patterns play an important role in the response of reefs to environmental change, including resistance to degradation and future adaptation potential. Many factors other than ocean currents affect the distribution of corals in the world, including the duration of larval survival and settlement success. Coral fertilization (the joining of male and female gametes) can happen inside the polyp (brooders) or externally (broadcast spawners), depending on species; in the pelagic post-release phase, coral larval survival can range from a few hours to months, and depends heavily on the lipid drops within the egg which can be used as a food reserve [11]. While some coral larvae can move distances of up to 1-1000 km, there is increasing evidence that the majority settle closer to home [25]. Factors that can affect the duration of the pelagic larval phase and the distance between sites of origin and settlement include species-specific traits such as larval behaviour and initial food reserves, as well as the presence of settlement cues, oceanographic and other environmental conditions, and predation.

Although existing patterns may shift as sea tempreatures rise and chemical changes take place in the oceans, both of which are likely to affect the initial life stages of corals, it is important to know the distribution patterns of coral larvae under current oceanographic conditions. Understanding the factors that affect range and species distribution is an increasingly important and urgent consideration in the context of MPA management, as the impacts of change of climate change that are beginning to affect species distribution around the world. These impacts will have direct and indirect impacts on marine conservation areas. If species are to survive, both life history strategies and MPA design must be able to accommodate environmental change.

3.4. Genetic Connectivity and Hydrodynamics around Sulawesi

Genetic information contained within each organism is the basis of life and evolution. Genetic traits can enable the detection of important patterns, for example the relatedness and similarity between organisms both within and between nominal species [5, 26]. The reproductive isolation of specific population or the level and direction of connectivity between reproductively connected populations of an organism has major implications for conservation [4,6,7,13,20,26]. Genetic approaches using modern molecular biology methods can reveal patterns of value in designing ecologicaly meaningful MPA networks, for example through the identification of source and sink populations. network for MPA design, it can be started by providing information of genetic in target organism. In addition to such genetic data, it is important to consider several aspects of prime importance in ecological theory such as spawning patterns, phlylogeny, bio-geography and observed distribution patterns as well as physical oceanographic factors [12,26].

The genetic code of each individual is unique; nonetheless, traits are transferred to offspring, such that more closely related organisms share a greater proportion of their genetic codes, especially in certain regions of the genome [5]. Genetic kinship or connectivity relies on identifying and tracing a suite of inherited genetic traits, the presence or absence and the properties of which can be considered to represent the movement and evolution of an organism in space and time [13]. Modern molecular biology methods enable the isolation and sequencing os specific subsets of an organisms genetic material (DNA); the sequences produced can be used to obtain biological information on the target organism or organisms, for example determining the relative levels of kinship within a group of organisms and their relative positions in terms of descent from a common ancestor [5,13,26]. Such an analysis can be visualised in the form of a phylogenetic tree. Relating such relationships with spatial distribution data can enable the detection of genetic population structure and connectivity, and can thus be used to inform conservation management [27].

Hydrodynamics play an important role in delivering the genetic material of marine organisms from one location to another. One of example of a multidisciplinary approach combining the application of genetics and hydrodynamics to the study of hard coral larval/planula phase dispersal and recruitment is the study on the endangered coral *Acropora cervicornis* in Florida [7]. This study found that conditions at the relase site played a major role in determining genetic diversity and distribution pattern. This work enabled the design of an MPA network based on the population connectivity patterns identified.

The highly biodiverse seas around Sulawesi [23] occupy a strategic position at the intersection of the Sulawesi Sea, Pacific Ocean, Banda Sea, Flores Sea and Java Sea. Despite the overall dominance of the ITF, the finer scale currents within this area are still poorly understood especially to the east of Sulawesi Island [15]. In addition to the current patterns, the presence of thousands od small islands, mostly relatively close to one another or to the Sulawesi Island coast, can be considered likely to contribute to coral genetic connectivity, even for species with short larbval durations, e.g. through the stepping stone effect.

Recent research [21] points to an unexpectedly complex genetic structure in the widespread coral *Lobophyllia corymbosa*. Samples were collected from the western (Makassar Strait) coast of Sulawesi (Palu and Mamuju), the eastern (Tolo Bay) coast (Luwuk Banggai) and souther (Gulf of Bone) coast (Sinjai). This study found that, in the complex geographic conditions around Sulawesi, geographic distance may not be a good indicator of connectivity. Distant populations may be more closely related, genetically, than nearby populations, for example Palu was more closely related to Luwuk than to Mamuju. Thus, despite their relative proximity, and the high connectivity which could be expected through the medium of the ITF, Palu and Mamuju populations of this coral do not appear strongly connected. This finding throws doubt on the ability of current and future MPA sites along the Makassar Straits to support one-another in source-sink terms, and at the very least requires a finer scale evaluation of the distances at which connectivity operates within this seaway. Furthermore, there appear to be unique alleles indicative of reproductively isolated populations, especially in Luwuk, possibly indicating an exceptionally high level of self-recruitment at this site, or alternatively a role as sink for such a population with a unique evolutionary history. This finding is of importance in the ccontext of the recently gazetted Banggai Dalaka MPA. Complex but as yet poorly understood hydrodynamic patterns, seasonal factors which play a major role in this monsoonal equatorial region, and local habitat typology, are some of the factors which may be driving the observed patterns. This study demonstrates the need for further research into genetic patterns around Sulawesi, and the application of results to MPA design and management in this area and other regions around the world.

References

[1] FAO 2012 The State of the World Fisheries and Aquaculture. (Rome : FAO) 209 pp

[2] Susanto H A 2011 Progres Pengembangan Sistem Kawasan Konservasi Perairan Indonesia: A Consultancy Report (Jakarta : Kerjasama Kementerian Kelautan dan Perikanandengan Coral Triangle Support Partnership) 35 p

[3] Pandolfi J M, Bradbury R H, Sala E, Hughes T P *et al* 2003 Global Trajectories of The Long-Term Decline of Coral Reef Ecosystems *Science* **301** 955-958

[4] Palumbi S R 2003 Population Genetics, Demographic Connectivity, and The Design of Marine Reserves *Ecol. Appl.* **13** 146-158

[5] Lundgren P 2011 *Genetics and Genetics Tools in Coral Reef Management* (Australia : Australian Government)

[6] Almany G R S R, Connolly D D, Heath J D, Hogan G P *et al* 2009 Connectivity, Biodiversity Conservation and The Design Of Marine Reserve Networks For Coral Reefs *Coral Reefs* **28** 339–351

[7] Heymond E M and Vollmer S V 2010 Genetic Diversity and Connectivity in the Threatened Staghorn Coral (*Acropora cervicornis*) in Florida *PLoS ONE* **5** e8652 (doi:10.1371/journal.pone.0008652)

[8] Zubillaga A L, Márquez L M, Cróquer A and Bastidas C 2008 Ecological and genetic data indicate recovery of the endangered coral *Acropora palmata* in Los Roques, Southern Caribbean. *Coral Reefs.* **27** 63-72

[9] Babcock R C and Heyward A J 1986 Larval Development of Certain Gamete-Spawning Scleractinian Corals *Coral Reefs* **5** 111-116

[10] Harrison P and Wallace C 1990 *Reproduction, Dispersal and Recruitment of Scleractinian Corals Ecosystems of The World* (Coral Reefs Vol 25) ed Z Dubinsky (Amsterdam : Elsevier Science Publishers) Chapter 7 133-207

[11] Wood E M 1983 R*eef Corals of the World: Biology and Field Guide* (New Jersey : TFH Publ. Inc)

[12] Jackson J B C 1986 Modes of dispersal of clonal benthic invertebrates: consequences for species distributions and genetic structure of local populations *Bull. Mar. Sci.* **19** 588-606

[13] Hellberg M E, Burton R S, Neigel J E and Palumbi S R 2002 Genetic Assessment of Connectivity among Marine Populations *Bull. Mar. Sci.* **70** 273–290

[14] Jones O A and Endean R 1973 *Geology* (New York: Academic Press) 480 pp

[15] Ambo-Rappe R and Moore A M 2019 *Sulawesi Seas, Indonesia* (World Seas: An Environmental Evaluation, Volume II: The Indian Ocean to the Pacific (Second Edition) ed C Sheppard (USA: Elsevier Academic Press) pp 559–582

[16] Wiadnya D G R, Djohani R, Erdmann M V, Halim A *et al* 2005 Kajian Kebijakan Pengelolaan Perikanan Tangkap di Indonesia: Menuju Pembentukan Kawasan Perlindungan Laut *Jurnal Penelitian Perikanan Indonesia* **11** 66 – 77

[17] Yulianto I, Herdiana Y, Halim M H, Ningtias P *et al* 2013 Spatial analysis to achieve 20 Million Hectares of Marine Protected Areas for Indonesia by 2020 (Indonesia: Wildlife Conservation Society and Marine Protected Areas Governance, Bogor)

[18] Bell J J, Smith D, Hannan D, Haris A *et al* 2014 Resilience to disturbance despite limited dispersal and self-recruitment in tropical barrel sponges: implications for conservation and management *PLoS One* **9** e91635

[19] Knittweis L, Kraemer W E, Timm J and Kochzius M 2009 Genetic structure of *Heliofungia actiniformis* (Scleractinia: Fungiidae) populations in the Indo-Malay Archipelago: implications for live coral trade management efforts *Conserv. Genet.* **10** 241-249

[20] Moore A M, Ndobe S and Jompa J 2017 A site-based conservation approach to promote the recovery of Banggai cardinalfish (*Pterapogon kauderni*) endemic populations *Coast. Ocean. J.* **1** 63–72

[21] Umar W, Jompa J and Tassakka A C M A R 2018 Genetic Diversity and Geographical Gene Flow Patterns of Spawning Broadcast Coral *Lobophyllia corymbosa* in The Sulawesi Waters as A Coral Triangle Area *IOP Conf. Ser. Earth Environ. Sci.* **116** 012060 (10.1088/1755-

1315/116/1/012060)
[22] Carpenter K E, Barber P H, Crandall E D, Ablan-Lagman M *et al* 2011 Comparative phylogeography of the Coral Triangle and implications for marine management *J. Mar. Biol.* ID 396982 (http://dx.doi.org/10.1155/2011/396982)
[23] Veron J E, Devantier L M, Turak E, Green A L *et al* 2009 Delineating the coral triangle *Galaxea* **11** 91-100
[24] Kochzius M and Nuryanto A 2008 Strong genetic population structure in the boring giant clam, *Tridacna crocea*, across the Indo-Malay Archipelago: implications related to evolutionary processes and connectivity *Mol. Ecol.* **17** 3775-3787
[25] Jones G P, Almany G R, Russ G R, Sale P F *et al* 2009 Larval retention and connectivity among populations of corals and reef fishes: history, advances and challenges *Coral reefs* **28** 307-25
[26] Whittaker R J, Araújo M B, Jepson P, Ladle R *et al* 2005 Conservation Biogeography: Assessment and Prospects *Divers. Distrib.* **11** 3–23
[27] Buletin KBR4 2014 Konservasi Biodiversitas Raja Ampat *Buletin Raja 4* **7** ISSN: 2338-5421 (www.ibcraja4.com)