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THE EFFECTIVENESS OF ARTIFICIAL REEFS IN IMPROVING ECOSYSTEM HEALTH TO INCREASE CORAL REEF RESILIENCE

EFEKTIVITAS TERUMBU BUATAN DALAM MEMPERBAIKI KESEHATAN EKOSISTEM UNTUK MENINGKATKAN RESILIENSI TERUMBU KARANG

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ABSTRACT

Some coral bleaching phenomena related to climate variability (ENSO and IOD) lead to coral mortality resulting in ecosystem damage and decreased ecosystem health. Artificial reef is one of the management efforts adopted by stakeholders to restore coral reef conditions. Thriving artificial reefs could extend coral coverage and provide a new habitat for several marine organisms and divert anthropogenic pressure on natural coral ecosystems. This research aims to identify the impact of artificial reef installment on ecosystems and fisheries. Three indicators for healthy coral reef ecosystems were determined: the increase of coral cover, biofouling organism, and fish diversity. A variable to measure the artificial reef impacts on fisheries is fish production after installment. Data collection was done in 2017 in Bali, including the occurrence of coral bleaching, the number of artificial reefs installed, and the case of positive impacts of artificial reefs. The data were analyzed to measure any changes that occurred after the artificial reef installment. The results show that an artificial reef installment has a significant impact on increasing coral cover, fouling organisms, fish abundance, and species richness. The new community structure development varies among the artificial reefs depending on the environmental condition. However, the impacts of artificial reef installment could not be directly quantified on fish production due to unavailability monitoring data.

Keywords: artificial reefs, climate variability, resilience.

ABSTRAK

Beberapa fenomena pemutihan terumbu karang yang disebabkan oleh variabilitas iklim (ENSO dan IOD) menyebabkan kematian karang yang berakibat pada kerusakan ekosistem dan penurunan kesehatan ekosistem. Terumbu buatan merupakan salah satu upaya pengelolaan yang dilakukan oleh pemangku kepentingan untuk memulihkan kondisi terumbu karang yang rusak. Terumbu buatan yang berhasil dapat memperluas tutupan karang dan menyediakan habitat bagi organisme laut dan mengalihkan tekanan antropogenik pada ekosistem karang alami. Penelitian ini bertujuan untuk mengidentifikasi dampak pemasangan terumbu karang buatan terhadap ekosistem dan perikanan. Indikator kesehatan ekosistem terumbu karang yang digunakan adalah peningkatan tutupan karang, organisme penempel serta kelimpahan dan keanekaragaman ikan. Sedangkan indeks untuk mengukur dampak terumbu buatan terhadap perikanan adalah besarnya produksi perikanan pasca pemasangan terumbu buatan. Pengumpulan data sekunder dilakukan pada 2017 di sekitar perairan Bali, di mana data yang dikumpulkan berupa peristiwa pemutihan karang, jumlah terumbu buatan yang terpasang, dan dampak positif dari pemasangan terumbu buatan. Data-data yang terkumpul kemudian dianalisis untuk mengukur setiap perubahan yang terjadi setelah pemasangan terumbu buatan. Hasil penelitian menunjukkan bahwa pemasangan terumbu buatan mempunyai pengaruh yang signifikan terhadap peningkatan tutupan karang, organisme penempel serta kelimpahan dan kekayaan jenis ikan. Perkembangan struktur komunitas pada terumbu buatan bervariasi bergantung pada kondisi perairan. Namun demikian, dampak pemasangan terumbu buatan tidak dapat dihitung secara langsung terhadap produksi perikanan, karena ketidaktersediaan data pemantauan.

Kata kunci: terumbu buatan, variabilitas iklim, resiliensi.

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INTRODUCTION

Extreme conditions due to climate variability significantly impact to the marine ecosystems, including fish resources (Puspasari *et al*., 2015) and their habitats. El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) are two kinds of phenomena related to climate variability. These may cause disrupted sea water temperature, generally indicated by a significant increase or decrease in sea surface temperature (SST).

The increase of water temperature is one of the significant stressors for coral reef ecosystems that generate coral bleaching. In Indonesia, mass coral bleaching occurred several times reported in 1997 by Johan & Quinn (2014), in 2010 by Wouthuyzen *et al*. (2017), and in 2015 - 2016 by Ampou *et al*. (2017). All those fenomena were caused by a sudden increase in water temperature. According to De Carlo *et al*. (2017), the slight rise in seawater temperature in a short period does not cause coral bleaching. Instead, the short-term extreme temperature increasing or long-term period of not-so-high temperature exposure causes mass coral bleaching and sometimes followed by coral mortality.

The damage of coral reef ecosystems disrupts their ecological roles and functions. Restoration and rehabilitation efforts can increase ecosystem health to support fish and other associated organisms. There are some tools to restore destroyed coral reefs and mitigate their loss (Lindberg & Seaman, 2011). The artificial reef is one of the most successful habitat restoration efforts that have been widely applied. The artificial reef provides a new substrate for coral larvae to settle and develop a unique ecosystem. Some studies showed that the installment of artificial reefs in some locations impacted the increase of fish population around the installment area (Yanuar & Ainurrohim, 2015; Manembu *et al*., 2014). The success of artificial reefs to improve ecosystem health is mainly related to the increasing ecosystem complexity. Moreover, according to Dufy *et al*. (2016), more diverse communities have a higher resistance to climate change. Three indicators to measure the success of artificial reefs as a rehabilitation tool are in form of the increasing in coral coverage and in biodiversity, as well as to having a positive impact on fisheries.

This paper aims to present a description of the role of artificial reefs in improving reef ecosystem conditions through quantitative analyses of some indicators.

METHODOLOGY

This current work used secondary data to analyze. The data were collected from previous studies on artificial reef development and fisheries monitoring data of the Badung District Government of Bali Province, NGOs data and stakeholder participatory meeting (workshop) held once in Gianyar Bali on October 3rd, 2017.

Stakeholder participatory meeting (workshop) was held to collect data and information on the artificial reef program and its impact on ecosystems around Bali Island. Stakeholders involved in the participatory meeting have different backgrounds as the aim of the meeting to collect data from various stakeholders. Stakeholders composition are the Marine and Fisheries Agency of Bali Province, Marine and Fisheries Office of Badung Regency Bali, local government of Les Village and Bondalem Village in Buleleng Regency, Bali, The Institute of Coastal and Marine Management of Denpasar (BPSPL), reef fish exporter (UD. Pulo Mas) fishermen that fished coral reef fishes and some NGOs that have a work program in coral reef management (Indonesia Nature Foundation, Nusa Dua Reef Foundation, Reef Check Indonesia, Coral Triangle Center, Conservation International).

All the data used in this study are taken from some studies on artificial reefs published in scientific journals and annual books. We also used unpublished data collected from Indonesia Nature Foundation (LINI). All data collected are described in Table 1.

The data were then listed, sorted, combined, reanalyzed, and for several monitoring data from the same artificial module were redrawn to have a time series monitoring graph. The data then descriptively analyzed to describe changes in variables that we put as an indicator of the growth of an artificial reef, such as coral coverage, the number of fouling organisms, coral recruit attachment, and reef fish productions.

RESULTS AND DISCUSSION

Coral bleaching related to elevated temperature

There were some cases of global mass coral bleaching phenomena caused by warmer SST related to climate variability. The first case recorded in Indonesia occurred in 1982 - 1983 (Suharsono & Kiswara, 1984). The second case occurred in 1997/1998 when the earth experienced dramatic changes in temperature. It coincided with the significant El Niño event that started in early 1997, followed by a rapid switch to La Niña in middle 1998 (Wilkinson & Hodgson, 1999). The third one was in 2010, and the latest was in 2015/2016, which was the worst mass coral bleaching ever happened, caused by the increase of seawater temperature about 2.2°C for three months consecutively (Puspasari *et al*., 2018). Coral bleaching cases related to climate variability phenomena in Indonesian waters are shown

Table 1. The list of secondary data gathering from different sources.

Data	Remark	Data source
Coral cover increase in artificial reef	Scientific journal	Aziz (2010); Hartati (2008)
Fouling organism attachment	Book	Puspasari & Oktaviani (2018); Syams *et al*. (2007b)
Coral recruit attachment	Scientific journal	Aziz *et al*. (2011); Fadli *et al*. ()2012; LINI foundation (2017) Primary data in 2017
Number of fish species around artificial reef	Scientific journal	Mujiyanto & Hartati (2011); Hartati *et al*. (2006); Satria & Mujiyanto (2011); Wasilun *et al*. (1991); Edrus *et al*. (1996); Edrus (2002); Hartati *et al*. (2006); Oktaviani *et al*. (2016); Manembu *et al*. (2014)
Production of reef fishes	Scientific journal Annual book of Fisheries statistic data	Hartati *et al*. (2006); Dinas Kelautan dan Perikanan, Badung District, Bali.
Production of ornamental shrimp in shrimp pond	Production data (unpublished data)	Indonesia Nature Foundation
Production of ornamental fish from artificial reef	Production data (unpublished data)	Indonesia Nature Foundation

in Figure 1.

Several massive coral bleaching occurred in Indonesian waters were coincided with extreme events caused by ENSO and IOD. High SST anomalies that exceed the coral reef threshold can cause bleaching on some coral species. The strength of ENSO influences the bleaching level. In 2016, El Niño was extreme and caused more massive bleaching and larger impacted areas (Figure 2), while in 2010, it was at a moderate level. According to Wothuyzen *et al*. (2017), coral bleaching occurred in 2016 had the same pattern as the 2010 event, which started, developed, and finished in the same periods of March to June, with different bleaching strengths. The condition of coral bleaching is set to worsen due to scientists' prediction that SSTs tend to increase within 50 years due to global climate change.

Coral reef restoration in Indonesian waters

The first officially reported installment of artificial reefs in Indonesian waters was in 1989. In that time the Government of Jakarta Province sank about 60,000 units of becak (traditional three wheels non-engine transportation) in Jakarta Bay, then followed by the Ministry of Marine Affairs and Fisheries that

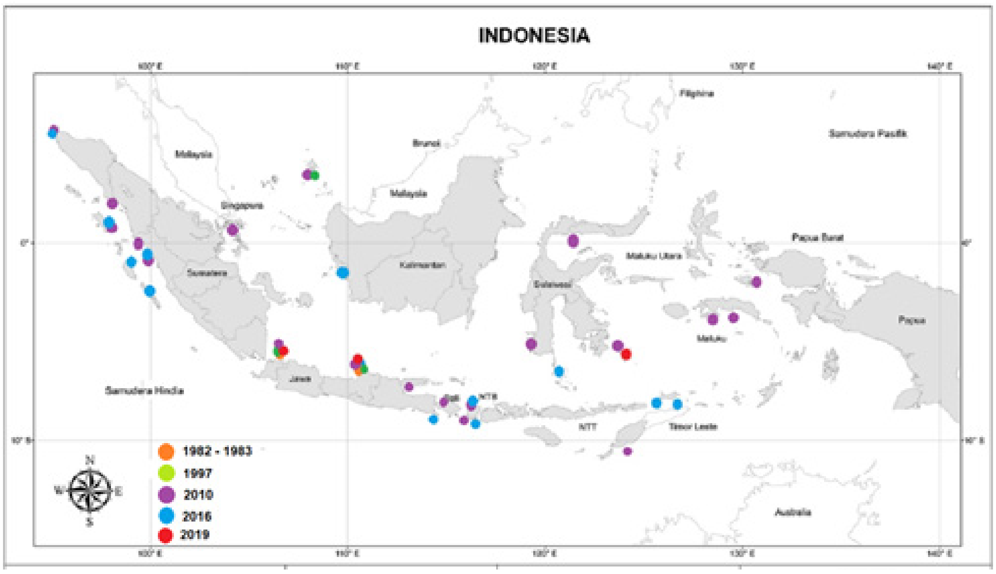

Figure 1. Distribution of coral bleaching phenomena in 1983 - 2019 (compiled from Suharsono & Kiswara (1984), Wilkinson & Hodgson (1999), RCI & MMAF (2016), Wouthyuzen *et al*. (2017), Reef Check Indonesia (2017), http://www.mongabay.co.id (date accessed on 20 February 2020).

installed more than 1,700 units of artificial reefs in 29 locations in Indonesia (Azis, 2010). Several materials and structures of artificial reefs, such as substrate block, chamber block, breakwater block, reef ball, bio-rock, and bio-reeftek, have been commonly applied in Indonesian waters that showed any different results in coral growth, diversity, and other ecological impacts.

Coral reef restoration, such as artificial reef, is an effort adopted by stakeholders to recover destructed coral reefs due to anthropogenic and climate variability causes. Artificial reefs are expected to rehabilitate coral reef ecosystems by creating new habitat for coral and other associated organisms to live. Installment of artificial reefs becomes a program for habitat rehabilitation, particularly for tourism purposes. Bali waters are some areas where artificial reefs were mostly installed for any different purposes. In 2017, coral reefs around Bali Island were 14.89% in excellent condition, 36.61% in good condition, and 15.49% in bad condition (Agency of Marine and Fisheries, Province of Bali, 2017). In collaboration with other stakeholders, such as NGOs, tourism agents, private companies, and local communities, the local government of Bali Province rehabilitated degraded ecosystems by installing artificial reefs. Table 2 shows the list of artificial reefs installed in Bali waters done by the Government, NGOs, and local communities. Due to tourism purposes, many artificial reefs around Bali have diversity in shape as diving spots for marine tourism. Figure 2 shows several forms of artificial reefs in Bali.

Ecological impacts of artificial reefs

The main impact of artificial reefs on the ecosystem is the increasing the health of the ecosystem. Some data recorded a significant effect of artificial reef installment in expanding the ecosystem's biodiversity through increasing the coral coverage, the number of species and abundance of some species around those artificial reefs (Aziz, 2010; Desistiano, 2008; Hartati *et al*., 2006).

The increase in coral coverage

The successful artificial reef could increase coral coverage, and some studies showed significant increases in coral coverage time by time in the new developed artificial reefs. In Seribu Islands, Azis (2010) showed coral coverage increasing of 5.97 % from the initial condition after ten years of installment. In Jemeluk Bay of Bali, Hartati (2008) showed that coral coverage increased 58.59% after 15 years of installment. Another case study showed in Mandeh Bay, West Sumatera, where coral coverage increased by 6.67 % after two

Table 2. Some artificial reefs installed in Bali.

Location	Area (m²)	Number of units	Installer
Ds. Tejakula, Buleleng	166	45	DKP, Desa, NGO
Ds. Penuktukan, Buleleng	281	76	DKP Prov Bali, Desa, LSM, Bupati
Ds. Tulamben, Karang Asem	248.5	125	MoMAF, NGO, Swasta
Ds. Jemeluk, Karang Asem	3,789.75	125	Desa, BUMN, Swasta
Samuh, Nusa Dua		116	NDRF
Conrad, Nusa Dua		6	NDRF
Nusa Dharma, Nusa Dua		36	NDRF
Mengiat, Nusa Dua		23	NDRF
Amanusa, Nusa Dua		6	NDRF
St. Regis, Nusa Dua		43	NDRF
Batu Gede, Nusa Dua		32	NDRF
Tj. Benoa		2	NDRF
Pandawa, Nusa Dua		30	NDRF
Abang island, Batam		10	BPPT
Mandeh Islands, West Sumatera	48	240	MoMAF
Pasir Putih, Situbondo			MoMAF
Menjangan Island, Bali		50 (bioreefteck)	MoMAF
Lovina Beach, Bali		28 (bioreeftecck)	MoMAf
Kerobokan, Buleleng, Bali		47 (bioreeftek)	
Eretan, Indramayu		150	MoMAF
Brebes, Central Java		150	MoMAF
Seribu Island		72	MoMAF, IPB
Awang Bay, West Nusa Tenggara		30	MoMAF
Bumbang Bay, West Nusa Tenggara		30	MoMAF

DKP: Department of Marine and Fisheries, Bali Province; MoMAF: Ministry of Marine Affairs and Fisheries
NGO: Non-Government Organisation, NDRF : Nusa Dua Reef Foundation; BPPT: Agency of Assessment and Aplication of Technology

Figure 2. Several types and shapes of artificial reefs installed in Indonesia (clockwise direction) (figure is taken from various sources with permission to the owner).
(a) fishdome (https://lini.or.id/locations/bali/coral-reef-restoration/),
(b) pyramid (Oktaviani & Wiadnyana, 2018),
(c) concrete block for lobster (Mujiyanto *et al*., 2018), and
(d) bioreeftek (Andayani & Ampou, 2018).

years of deployment (Oktaviani *et al*., 2016). Figure 3 shows the increase of coral covers in an installed artificial reef in Jemeluk Bay and Seribu Islands.

The increase in fouling organisms

Fouling organisms accumulated on immersed surfaces of artificial reefs are used to be the first organisms in the succession process of artificial reefs. New immersed artificial reefs characterized by an abundance of empty space (Krohling *et al*., 2006). Empty space showed a decreasing trend over time after submersion, concomitant to the substrate's occupation by the fouling organisms. The invasion of fouling organisms is getting thicker by the time, as shown in the monitoring of fouling organisms in artificial reef deployed in Mandeh Bay. The artificial reef that had been immersed for 170 days had a higher density of fouling organisms (39 - 43 ind./m^2) compared to that had immersed for 80 days (13 ind./m^2), as shown in Figure 4. (Puspasari & Oktaviani, 2018). Species richness is also increasing with time. In the 170 days immersed artificial reef, there were six species found of fouling organisms, while the 80 days submerged artificial reef had only five species found of fouling

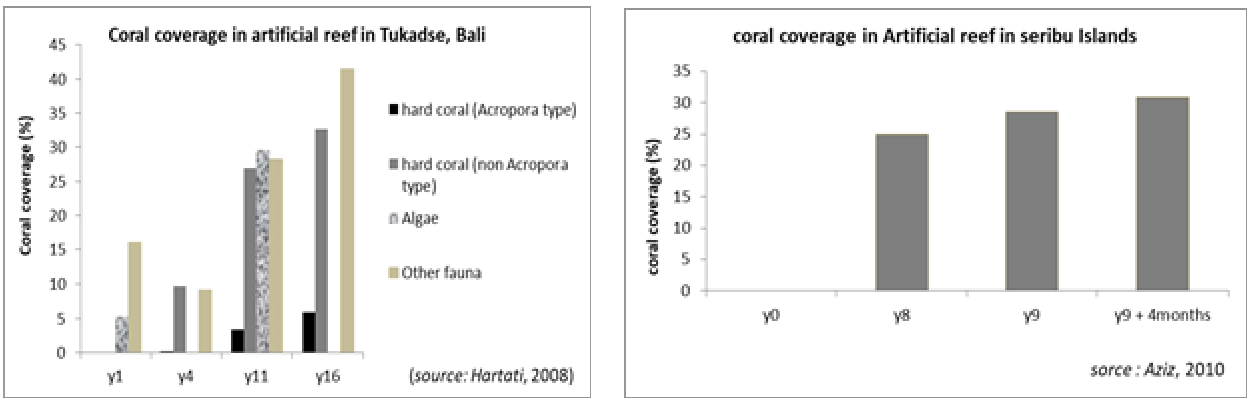

Figure 3. The increase of coral coverage in artificial reef installed in Tukadse Bali and Seribu Island, reanalyzed and redrawn from Hartati (2008) and Azis (2010).

organisms. Another case was the artificial reef installed in Saleh Bay (Figure 5). Fouling organisms was seen in a significant number after four months installed, the number of fouling organism species found was 16 species then increased to 22 and 29 species after six months and ten months installment respectively, as described by Syams *et al*. (2007).

An artificial reef provides a new substrate for new coral recruits to settle. Attachment of coral larvae is evidence of the success of artificial reefs; it could indicate that the substrate of the artificial reef is suitable for the development of a new coral reef ecosystem. From plain concrete becomes a new colony of coral. It might take time to grow new colonies; however, in a suitable environment, new colonies can grow and become a new coral community. Figure 6 showed some developments of coral recruits attached in the artificial reef installed in Buleleng Bali, Weh Island Aceh, and Seribu Islands. Those three artificial reefs are different in the time of installment. The set of artificial reefs installed in Buleleng Bali was the newest (about 15 months installed) while in Weh Island and Seribu Islands are older, respective about three and nine years installment with significant increases in coral recruit.

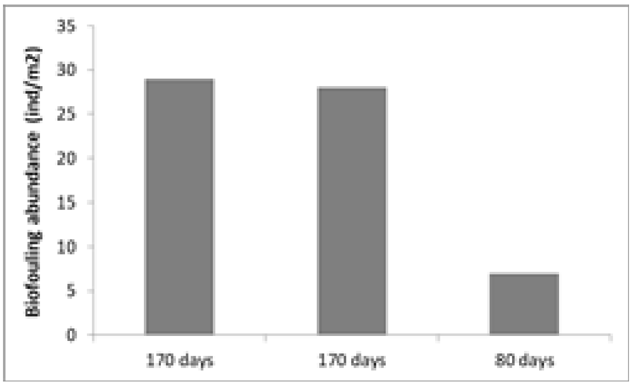

Figure 4. Density of fouling organisms in artificial reef submersed for 170 days and 80 days (Source: Puspasari & Oktaviani, 2018).

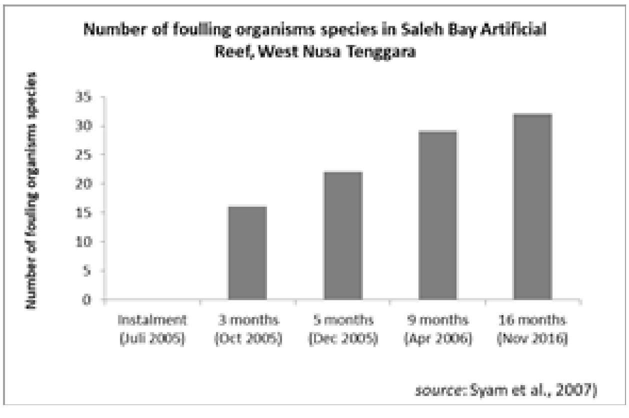

Figure 5. Development of number of fouling organism attached in artificial reef.

The increase in fish abundance and number of species

Some studies showed that plots with artificial structures had significantly higher fish abundance, species richness, biomass, and species diversity than natural damaged ones (Ferse, 2008; Koeck *et al*., 2011; Awuy *et al*., 2017). The availability of new habitat will attract some fishes and other organisms to inhabit the artificial reef (Pascaline *et al*., 2011). Our study showed that there were significant increases in fish abundance and number of species in artificial reefs, which had already switched into new ecosystems. The complexity of the fish population in the developed artificial reef depends on the time of its installment and the environmental condition surrounding the artificial reef. Several cases from different artificial reefs showed that in the development phase of an artificial reef, the number of fish and fish species were significant until they reached their steady-state condition. The time when a steady-state comes is different from one another.

Figure 7 showed the different conditions of fish numbers and the number of fish species development in the diverse artificial reef. In Mandeh of West Sumatera artificial reef, the number of fish school around artificial reef was significantly increased even only in two months after installment and raised more than five times after five months installment of the artificial reef (Oktaviani *et al*., 2016).

The steady-state condition could be seen from more prolonged monitoring of installment artificial reefs in Saleh Bay (West Nusa Tenggara), Jemeluk Bay (Bali), and Ratatotok Bay (North Sulawesi), as described in Figure 7. Steady-state condition is characterized by an insignificant increase of fish population in the new ecosystem. In Saleh Bay, the fish population's negligible increase occurred at more than 60 months (about five years) after installment. In Jemeluk Bay, after 15 years of installment, the number of fish species in the artificial reef increased about 3.2 times compared to the first installment, while fish abundance increased 25.6 times. However, the fish population's complexity is higher after ten years of artificial reef installment and showed the maximum complexity of the fish population. Then the population complexity decreased due to any reason. The development of the fish community structure of the artificial reef was also shown in Ratatotok (North Sulawesi), installed in 1999. Manembu *et al*. (2012), who conducted fish community monitoring in 2009, 2010, and 2011, showed no significant difference in fish abundance and the number of fish species, indicating that the fish community had reached their stability by

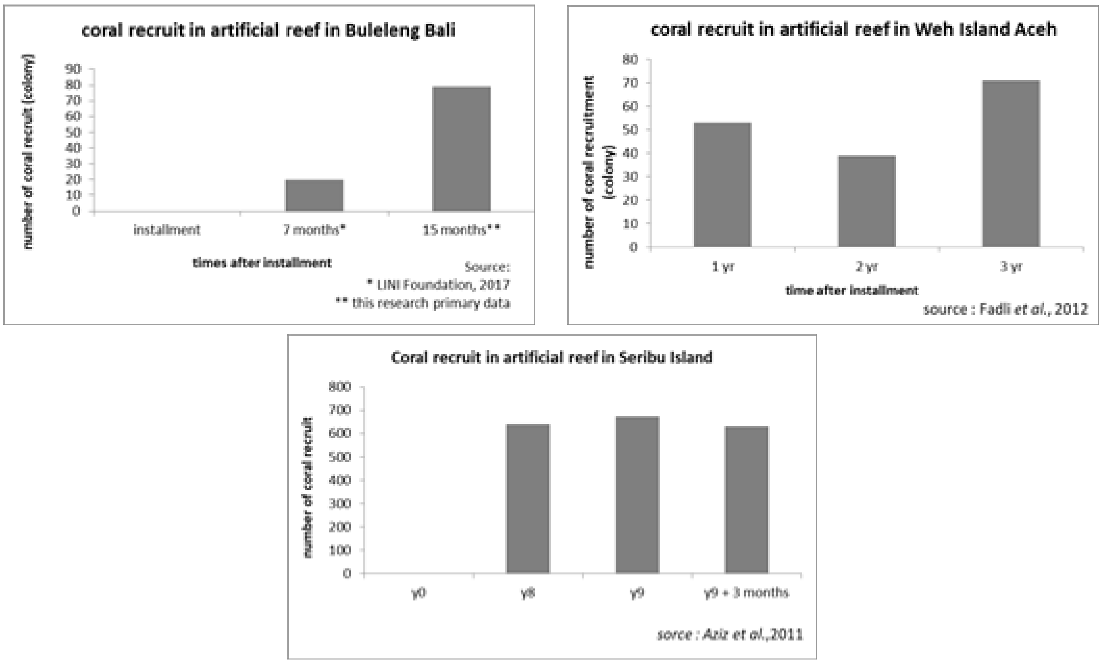

Figure 6. The increase of coral recruit colony in the artificial reef: a. hard corals and soft corals, b. long-term recruitment, and c. short-term recruitment. This figure is modified from Fadli *et al*. (2012), Aziz *et al*. (2011) and unpublished data from Indonesia Nature Foundation (2017).

2009 or earlier. The achievement of building a stable fish community in Ratatotok showed that the artificial reef had successfully developed a new coral reef ecosystem.

The main objective of artificial reef installations is for habitat restoration to improve the ecological role of damaged coral reefs, such as feeding, nursery, and spawning habitat of some reef related species. However, some researches showed that artificial reefs

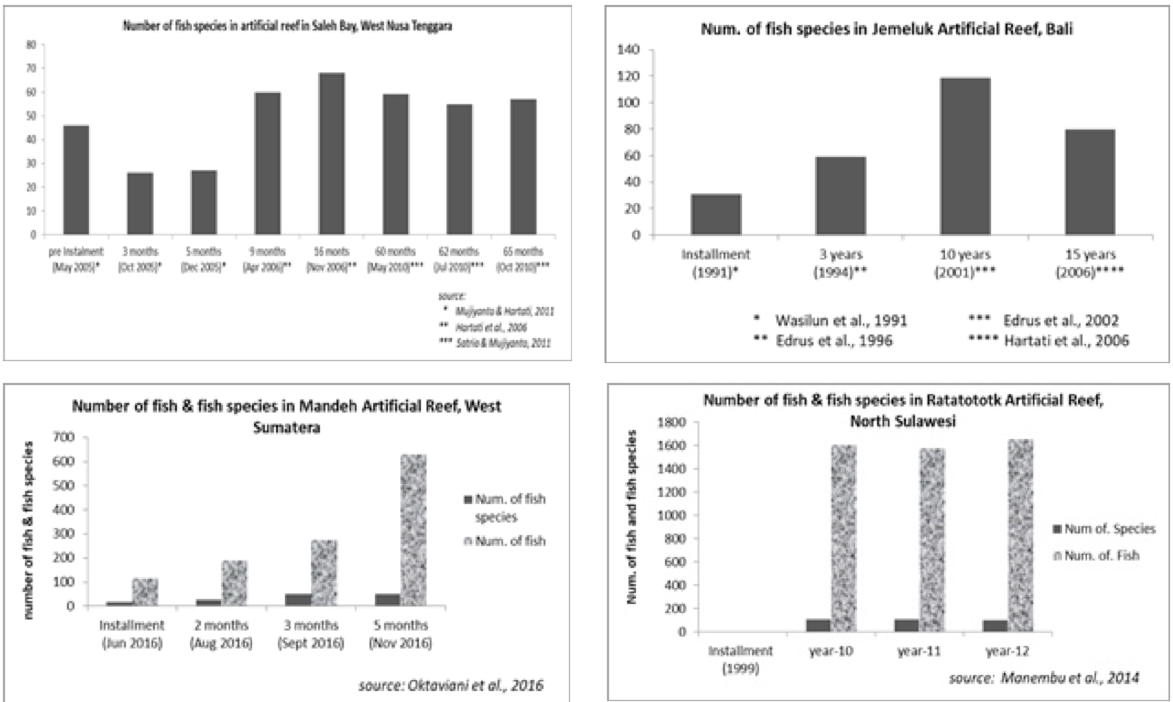

Figure 7. The development of the number of fish found around several installed artificial reefs: Reanalyzed and redrawn from Mujiyanto & Hartati (2011), Hartati *et al*. (2006), Satria & Mujiyanto (2011), Wasilun *et al*. (1994), Edrus *et al*. (1996), Edrus (2002), Oktaviani *et al*. (2016), and Manembu *et al*. (2014).

are more functioned as fish aggregation devices that attract fish from other areas to school and play around those artificial reefs. One of the success indicators of artificial reef installments is its impacts on fisheries. Fish assemblage and species richness of reef fishes in the artificial reef are highly correlated to the dimension and design complexity of the artificial reef, such as volume, the number of holes (Yanuar & Ainurohim, 2015), and void spaces (Pascaline *et al*. (2011). As the initial phase of new ecosystem development, there should be some fish attracted from other areas to school and play around artificial reefs (Koeck *et al*., 2011). Nevertheless, Koeck *et al*. (2011) showed that distance from the natural reef is not a factor influencing fish assemblage; the study found a high dissimilarity of species assemblage between the natural site and the artificial one.

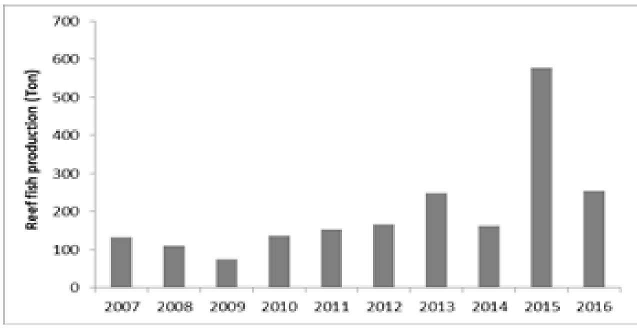

Figure 8. The trend of increasing production of reef fishes after the artificial reef installment in Badung District of Bali Province (Data plotted from Marine and Fisheries Office of Badung District, Bali Province, 2017).

The Impact on Fisheries

As a damaged habitat is restored and its role as a fish aggregation device, artificial reefs should impact the increase of reef fish production around the installment area. However, the fisheries impact is quite tricky to analyze due to its long-term impact.

The observation on artificial reefs installed in Saleh Bay, showed an insignificant increase in catch around the artificial reef area after a year installment as shown in Table 3. It seems that one year is too short to know the impact of the artificial reef installment on fish catch.

The significant impact of artificial reef installment on fish production could be seen in Badung District, Bali, where the Government of Badung District in collaboration with local community and NGOs developed some artificial reefs around Badung waters since 2007. Based on fisheries statistical data, the reef fish production has increased gradually since 2009, about three years after artificial reefs installment (Figure 8). Insignificant increase in fish production probably caused by short period observation after installment. Coral reef community was starting to develop in a year; therefore, the fish community was quite similar to the previous condition. Fish communities were found schooling around the new habitat, mostly foragers from other areas.

Another case that showed the success of artificial reefs in increasing fish production is the installment of shrimp pots in Buleleng District, North Bali. Shrimp pot is a small artificial reef with a specific design applied for ornamental shrimp habitat. The Indonesia Nature Foundation, in collaboration with the local community in Les Village, Buleleng, developed the application of shrimp pot to restore ornamental shrimp habitat. Ornamental shrimp fishing had become a livelihood for many fishermen in Les Village, shrimp habitat restoration became one of their programs to support sustainable ornamental shrimp. There were six species of ornamental shrimp found in installed shrimp pots, there are camel shrimp (*Rhinchocinetes durbanensis*), skunk cleaner shrimp (*Lysmata amboinensis*), two spesies of banded coral shrimp (*Stenopus sp* and *S. hispodus*), violet banded boxer shrimp (*S. tenuirostris*), and red reef shrimp (*Enoplometopus occedentalis*) (Indonesia Nature Fondation, unpublish data, 2017). Since the shrimp pots were installed in 2011, the production of ornamental shrimp had increased for the next three years, then decreased at the fourth year except for *Lysmata amboinensis*. Figure 9 shows the

Table 3. Production of reef fishes around the artificial reef installment area did not increase with time (Hartati *et al*., 2006).

Time		**Catch (Kg/trip/gears)**	**Remark**
2005	April	2.20	In the year of artificial reef installment
	June	1.40	
	October	1.65	
	December	1.40	
2006	April	1.65	1 year after installment
	November	1.26	

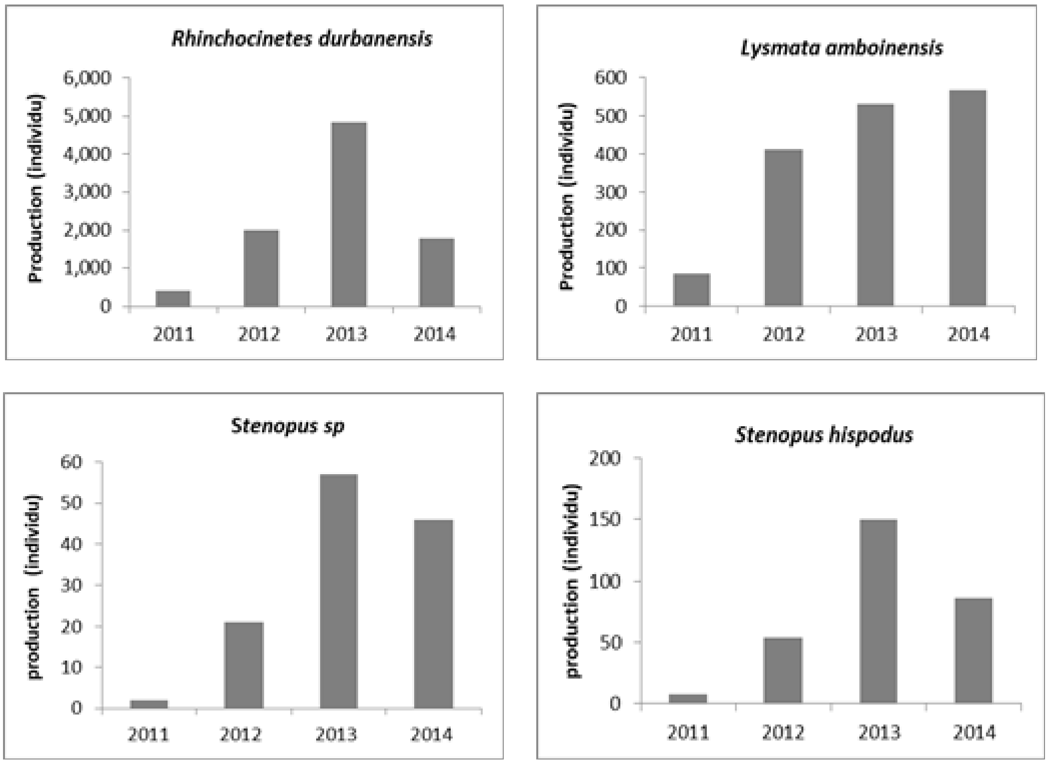

Figure 9. Production of ornamental shrimps in Les Village Buleleng District Bali (data used for analyzing supported by Indonesia Nature Foundation, unpublished data, 2017).

trend of four dominant shrimp species caught in shrimp pots.

Besides those six species of ornamental shrimp, there were three species of ornamental fishes experienced increases in production: *Pomachantus imperator* (bluestone), *Halichoeres chrysus* (local name: keling kuning), and *Doryrhamphus dactyliophorus* (local name: bajulan zebra). There were also four species of reef fishes never found previously: bannerfish (Heniochus Monoceros), Janss pipefish (Doryrhamphus janssii), red lionfish (Pterois volitans), and two species of spot hogfish (Bodianus sp. and B. bimaculatus), as well as one species of red reef shrimp, *Enoplometopus occedentalis* (Figure 10).

As new or extended habitat, artificial reefs increase the complexity and stability of the reef ecosystem through increasing biodiversity. According to Rogers (2013), the high biodiversity of coral reefs means that response to a local and global stressor is anticipated. Every single species will differ in their ability to deal with stressors, including climate change. A diverse community and high biomass could buffer the systems against the negative impact of climate change (Duffy *et al*., 2016). The response of every species will vary even within populations. In the case some species are vulnerable to increasing temperature, some others will survive due to different specific physiological processes.

CONCLUSION

Artificial reefs give significant impacts on ecosystem health through increasing the coverage area and the species richness and abundance of biofouling organisms, coral settlements, and fish communities. The new community structure development might vary among the artificial reefs depending on the environmental conditions. However, sufficient time is

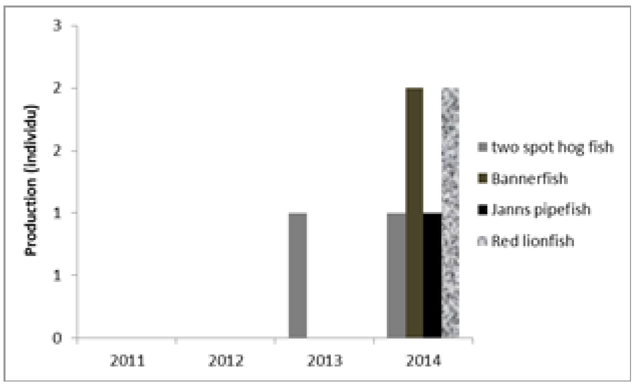

Figure 10. Production of bannerfish, Janss pipefish, red lionfish, and two spot hogfish around shrimp pot installed in les Village District Buleleng Bali (Indonesia Nature Foundation, unpublished data, 2017).

needed for the development of community structures in new habitats. Artificial reefs increase the complexity and stability of ecosystems that lead to the increase of coral reef resistance and resilience. Therefore, artificial reefs can be an option for mitigation strategies in dealing with climate change.

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REFFERENCE

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