BIODIVERSITAS
Volume 18, Number 2, April 2017
Pages: 681-688

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d180234

Coral larvae spreading based on oceanographic condition in Biawak Islands, West Java, Indonesia

CANDRA A. FITRIADI[1,♥], YAYAT DHAHIYAT[2], NOIR P. PURBA[3,♥♥], SYAWALUDIN A. HARAHAP[1], DONNY J. PRIHADI[1]

[1] Department of Marine Science, Faculty of Fisheries and Marine Science, Universitas Padjadjaran. Ged. Dekanat FPIK-UNPAD, Kampus Jatinangor, Jl. Raya Bandung-Sumedang Km 21, Jatinangor, Sumedang 45363, West Java, Indonesia. Tel.: +62-22-87701519, Fax.: +62-22-87701519, ♥email: candraaf@gmail.com

[2] Department of Fisheries Management, Faculty of Fisheries and Marine Science, Universitas Padjadjaran. Ged. Dekanat FPIK-UNPAD, Kampus Jatinangor, Jl. Raya Bandung-Sumedang Km 21, Jatinangor, Sumedang 45363, West Java, Indonesia

[3] KOMITMEN Research Group, Universitas Padjadjaran. Ged. Dekanat FPIK-UNPAD, Kampus Jatinangor, Jl. Raya Bandung-Sumedang Km 21, Jatinangor, Sumedang 45363, West Java, Indonesia. ♥♥email: noirpurba@gmail.com.

Manuscript received: 21 April 2016. Revision accepted: 3 April 2017.

Abstract. *Fitriadi CA, Dhahiyat Y, Purba NP, Harahap SA, Prihadi DJ. 2017. Coral larvae recruitment based on oceanography condition in Biawak Islands, West Java, Indonesia. Biodiversitas 18: 681-688.* This research aimed to know the recruitment pattern of planula in the Biawak Island. The dispersion of planula and corals recruitment as an important factor to determine the distribution of the adult corals. The spawning and brooding are the beginning processes of planula dispersion. Dispersion factors are highly influenced by water environment factors. The main factor in planula dispersion is sea currents, wind, tide, and bathymetry. The circulation of sea currents on Biawak Islands waters is influenced by the tidal movement. The results of research showed that Biawak Islands waters have mixed tide prevailing semidiurnal type of tidal movement. Currents of Biawak Islands waters moved from the northern toward the southern with a range of speed between 0.045-0.075 m/s on northeast and south and for west and north range of speed of sea currents are between 0.015-0.195 m/s, the sea currents movement of Biawak Islands waters was dominated by tidal movement. Biawak Islands have varying wind speed, the most direction of wind moved to northwestern toward southeastern by predominance speed 4.8-7.2 m/s. The results of research showed that planula on the Biawak Island moved to northern and northeastern at high tide and then moved to southern and southeastern at a low ebb with the furthest movement of planula on the Biawak Island was 2.2 km. The furthest movement of planula on the Gosong Island was 1.66 km and planula dispersed to the east and west region of Gosong Island, on the Cendikia Island planula dispersed to northern and eastern with the furthest movement of planula on the Cendikia Island was 0.44 km. Based on the movement of planula can be concluded that source of coral reefs on the Gosong Island derived from the coral reefs on the Biawak Island.

Keywords: Planula, coral recruitment, currents, oceanography, Biawak Islands
Abbreviations: BIEXRE = Biawak Exploration and Research, TRAX = Technical Research and Expedition, MYSEA = Marine Bio-Ecology Spatial Mapping, PODC = Padjadjaran Oceanographic Data Centre, DIKTI = Pendidikan Tinggi, UNPAD = Universitas Padjadjaran, KOMITMEN = Kelompok Studi Instrumentasi dan Survei Kelautan, MPA = Marine Protected Areas .

INTRODUCTION

The coral reef is one of the complex ecosystems and formed from solid calcium carbonate ($CaCO_3$), which is produced by mutualism symbiosis and other organisms that secrete calcium carbonate. Coral reef lives on the coast or areas that have to expose to light because to produce photosynthesis. Generally, corals reproduce in two ways: asexual and sexual. In sexual reproduction, ocean currents play an important role in the fertilization process, especially during spawning and planula phase (Richmond 1987; Roberts 1997).

In the spawning process, corals release ovum and sperm into the water column and began fertilization process in a few hours. The next step is planula floats and via ocean currents find a suitable substrate. The recruitment process means that planula will be attached to the substrate that is eligible to support growth. This mechanism is an important principle in maintaining and multiplying the adult populations of marine organisms (Underwood and Fairweather 1989; Hughes et al. 2000; Harii and Kayanne 2001). Planula will attach to the substrate of about 4 to 7 days after fertilization (Babcock and Heyward 1986; Harrison and Wallace 1990), the range of planula's maximum resistance is 26 to 78 days (Lugo-Fernandes 2001) and depends on physical and chemical stress including the ocean currents (Morgan 1995). Currents not only spread the planula, but more function is to support oxygen, food, the warm water for the manufacture of coral (Wood 1983). Currents is the movement of water resulting in the horizontal and vertical displacement of water masses and via atmosphere transfer the energy (Sverdrup et al. 1961).

This research focuses on spreading of planula in Biawak Islands, Indramayu region. Biawak consists of 3 islands and locates in Java Seas. Ocean currents play important role in this area affected by tides and monsoon (Siregar et al. 2017). This research focuses on the process of recruitment and will describe the main point of the three

island where the starting point. In the long term, this research will lead to Java Seas planula dispersal with oceanographic input. This research use oceanographic survey combine with an oceanographic model that lead to a new description about planula in Biawak. Since 2006 this island became MPA, and this research will lead the dispersal of planula in Biawak Islands. These islands become a remote island because of only <5 research found in the literature. By this research, the local government will have a guide to propose programs as we know the high diversity in Biawak.

MATERIAL AND METHODS

Study area

This research conduct in Biawak Islands in the Java Sea, Indramayu District, West Java, Indonesia with the area for the coral ecosystem around Biawak Islands. Biawak Islands is located in the north of Indramayu beach, or 06˚56'022" S and 108˚24'487" E. Several surveys were done in two years in October 2014, April and May 2015. We have eight plot of observation stationary refer to the coral ecosystem existence all around (three islands (Table 1, Figure 1).

The Biawak Islands consisting Biawak Island (the main island) Gosong Island, and Cendikia Island. These islands became Local Marine Protected Area (MPA) since

2006. The condition of oceanography in the Java Sea is affected by the existence of two monsoons, which are West Monsoon (WM) and East Monsoon (EM). The average deep of Java Sea is 40 meters and is located in South East of Sunda shelf (Ahmad and Pariwono 2012). Purba and Harahap (2013) found that bathymetry over Biawak Islands ranges from 5-60 meters and currents with 0.17-0.32 m/s. The corals component composer of Biawak Islands is dominated by hard corals from *Acroporidae* family, *Faviidae,* and *Poritidae*. A total of the genera found are 39 genera of 13 corals family. The biggest percentage of *Porites sp* genus existence is 20,58%, *Acropora* sp 11,59% and *Diploastrea sp* 9,15% (Darmasyah 2010; Nuriadi 2012; Purba and Harahap 2013).

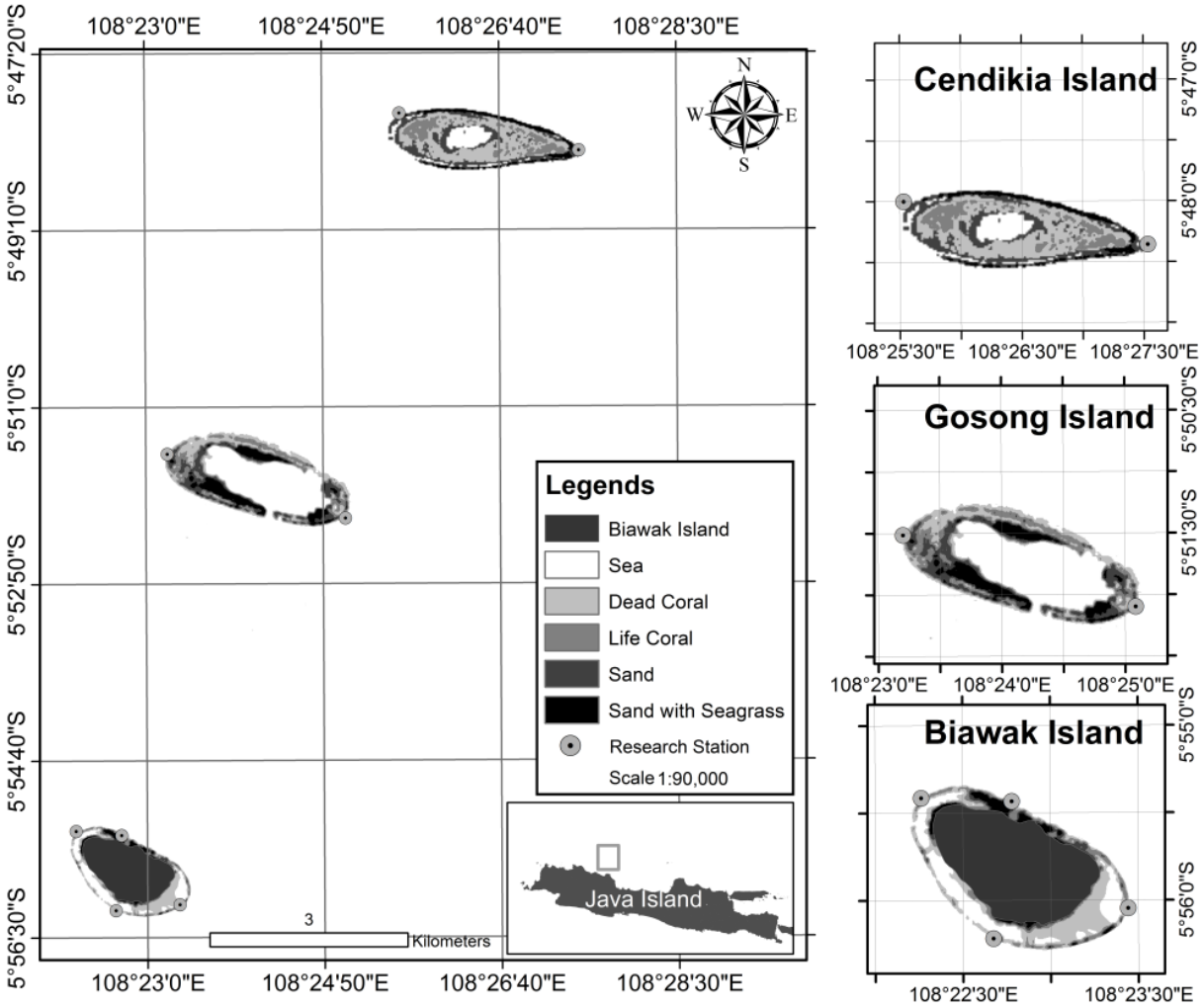

Figure 1. Map of Biawak Islands Biawak Islands, West Java, Indonesia and the coral distribution (source: Landsat TM 8)

Procedures

Planula parameter and hydrodynamic initial condition

Several parameters used in this research consists of some planula parameters and ocean hydrodynamic needed for particle tracking model. As we know the oceanographic condition that affects planula, we use tides, bathymetry, winds, and ocean currents. These parameters become hydrodynamics parameters that lead to simulation of planula. The planula weight used from several types of research because we do not have sufficient data. The increasing of planula's weight each day can be seen from the average volume of planula, maximum average volume of planula, maximum weight average of planula, specific weight average of planula with the assumption that all planula species had weight, maximum weight, volume, maximum volume, and the same specific weight. The modeling duration is 15 days with the interval of one hour per simulation for Biawak Island and seven days per season with the interval of one hour per simulation for three islands. Next, for modeling waters hydrodynamic research territorial, the parameters used are wind, tide and ocean bathymetric research territorial. Data used in this study can be found in Table 2, Table 3 and Table 4.

Simulation of planula distribution

Simulation process using particle tracking model where the hydrodynamics combine with planula weight. This simulation process used two steps to have the best description of the pattern. The first is ocean hydrodynamic model and the second scenario is combined growth of planula's weight each day which has changed into the growth of weight per second in which consists of planula distribution formula coefficient vertically. Particle tracking simulation technique used to display a movement or shift and disperse of the particle by using Langevin's formula.

$$dX_t = a(t, X_t)dt + b(t, X_t)\Sigma_t dt$$

When the particle starts to move in the water stream, the speed of particle will be increasing until it raises constant speed. The end of speed depends on the particle size and is explained in Stokes' Law.

$$W_s = \frac{(P_s - p).g.d^2}{18\mu}$$

Table 1. Position of planula source in Biawak Islands, West Java, Indonesia

Island	Station	Location	
		Lat. (S)	Long. (E)
Biawak	1	05°55'22.44"	108°22'15.59"
	2	05°55'32.52"	108°23'06.00"
	3	05°56'02.04"	108°23'31.55"
	4	05°56'06.72"	108°22'30.00"
Gosong	1	5°52'349"	108°24'143"
	2	5°52'110"	108°24'335"
Candikian	1	5°47'544"	108°25'414"
	2	5°48'246"	108°27'384"

Table 4. Oceanographic data and source

Parameter	Source
Bathymetry	http: //www.p3sdlp.litbang.kkp.go.id http: //topex.ucsd.edu/marine_topo/ BIEX RE 1 2012 BIEX RE 2 2013 MYSEA Project 2014
Wind	www.ecmwf.int (June 2014-May 2015)
Tide	Tidal Model Driver (Egbert and Erofeeva 2002) (June 2014-May 2015)
Currents	http: //coastwatch.pfeg.noaa.gov/erddap (March 2012)
Corals Image	http: //glovis.usgs.gov/ (Landsat 8 OLI Juli 2015)

Table 2. Volume and 50% Survival Time of planula in Biawak Islands, West Java, Indonesia

Species	Volume Planula (mm³)	50% survival time (day)	Source
Acropora hyancinthus	0.053	21	(Nozawa 2011)
Acropora latisela	0.058	4	(Graham et al. 2008)
Acropora digitifera	0.065	10	(Nishikawa and Sakai 2005)
Acropora japonica	0.065	14	(Nozawa 2011)
Acropora tenuis	0.065	25	(Nishikawa et al. 2003)
Acropora solitaryensis	0.08	14.21	(Nozawa 2011)
Acropora millepora	0.087	14	(Baird 2001)
Acropora valida	0.011	16	(Baird 2001)
Acropora gemmifera	0.0115	14	(Baird 2001)

Table 3. The average volume and maximum average volume of *Agaricia* in Biawak Islands, West Java, Indonesia

Parameter	*Agaricia humilis* (mm^3)	*Agaricia agaricites* (mm^3)	Source
Average volume (mm^3)	0.166	0.860	Godfried et al. 1983
Maximum volume (mm^3)	0.61	2.4	Godfried et al. 1983

Coral recruitment

To predict coral recruitment area on Biawak Island, the limitation of depth is used where the stopped planula is assumed to have been settled at the ground sea substrate with depth range used is about 5-25 meters.

The length of model simulation (15 days) based on the average of 50% survival time of planula *Acropora,* coral spawning time (Wijayanti 2012) and season (Munasik 2002; Kenyon 1992). The plot on the map not meant to represent planula densities in the field, because one large coral colony can release thousands of planula simultaneously. The first planula settles after 7 hours at depths 15 meters according to the result of the model. We assumed planula who stop moving on the model have to been settled at the ground sea substrate with the settlement occurred 100% by assuming substrate in Biawak Island waters has overgrown coralline algae.

Data analysis

Planula survival

For this model, we use 50% survival time data for the duration of a model because of compability of the computer in the simulation. Data volume used to figure on volume the average density, weight, and addition weight planula per day.

Hydrodynamic condition

The data used to model hydrodynamic are bathymetry, tide and the wind. The currents and coral image used as parameter additional to compare the model with reality.

RESULTS AND DISCUSSION

Condition of Biawak Island's oceanography

According to tides, Biawak Islands have mixed tide prevailing semidiurnal type. On the West Monsoon (December-February) the highest tide reach the number of 0.38 m and the lowest ebb is 0.34 m, on the Monsoon Transition 1 (March-May) the highest tide is 0.35 m and the lowest ebb is 0.34 m while on the Monsoon Transition 2 (June-August) the highest tide is 0.36 m and the lowest ebb is 0.3 m. Currents moved from the northern toward the southern with a range of speed between 0.045-0.075 m/s on northeast and south and for west and north range of speed of sea currents are between 0.015-0.195 m/s, the sea currents movement of Biawak Islands waters is dominated by tidal movement. Biawak Islands have varying wind speed, the most direction of wind move to northwestern toward southeastern by predominance speed 4.8-7.2 m/s. The influence of waves and currents that occur in areas of research in the waters of Biawak Island, Cendikia Island and Gosong Island reaches a depth of up to 4 m. In this research area moves from the current profile to the bathymetry in shallow areas or the edge so that in this case the current speed and wave height increased.

Planula dispersion pattern

The dispersion of planula that occurred on Gosong Island and Cendika Island are moving to the west and north and south and then back again to the starting plot (Figure 2). The dispersion of planula on the Biawak Island shows that planula which came from the northern part of the island were moving down to south through the eastern part of the island, planula which came from the southern part of the island were moving toward the south away from the island and planula which came from west island were moving to southeast away from the island. 24 hours after the first modeling day (Figure 3) the planula moved from the south to the northeast then moved towards the south again and some of them moved towards the northeast, some moved to the north (as shown by the arrow).

Planula from the Biawak Island moved to northern and northeastern at high tide and then moved to southern and southeastern at a low ebb with the furthest movement of planula on the Biawak Island was 2.2 km. The furthest movement of planula on the Gosong Island was 1.66 km and planula dispersed to the east and west region of Gosong Island, on the Cendikia Island planula dispersed to northern and eastern with the furthest movement of planula on the Cendikia Island was 0.44 km.

This movement of dispersion continued repeatedly each interval modeling from the beginning until the end of modeling or exactly for 15 days (after full moon). Some planula moved toward the northeast out from the border of modeling area, predicted planula from the Biawak Island make the recruitment process of coral on the Gosong and Candikian. The overall movement of planula on Biawak Island can be seen in (Figure 4). A pattern of this movement formed the wave up and down pattern that kept rising over time.

Coral recruitment prediction area on Biawak Island

Based on the results of modeling in March 2015, planula attached to the blacked area predicted will grow into adulthood and form coral reef ecosystems. The range depth planula that attaches to the floor of the waters is between 2-25 m below the sea surface. The area prediction A is 2.916 km^2 and for the area of prediction B is 1.614 km^2. The prediction An area depth range is between 0-42 m below sea surface while the depth range of prediction B is between 10-56 m below sea surface (Figure 5).

Discussion

Based on result and simulation, we showed that planula attached to the area came from the coral reef ecosystem in the northern and eastern region of Biawak Island. So, the presence of coral reef ecosystems in the northern and eastern parts of the island is very important to preserve the coral reef management. From surveys 2011-2015 with visual transect, we found that most of the coral reef around Biawak almost bleaching because of uncommon fishing that affects the corals.

Then, We suggest that DNA analysis between Biawak, Gosong, and Candikian coral reef is the other research to make the best conclusion. About the coral spawning, we must require the formation of areas zone the nucleus for ecosystem the coral reefs of the Biawak waters which the research is in the northern part to the east of the Biawak Island. Required advanced study parameters additional such as salinity, sea surface temperature and predation to planula survival. Biawak Island moved to northern and northeastern at high tide and then moved to southern and

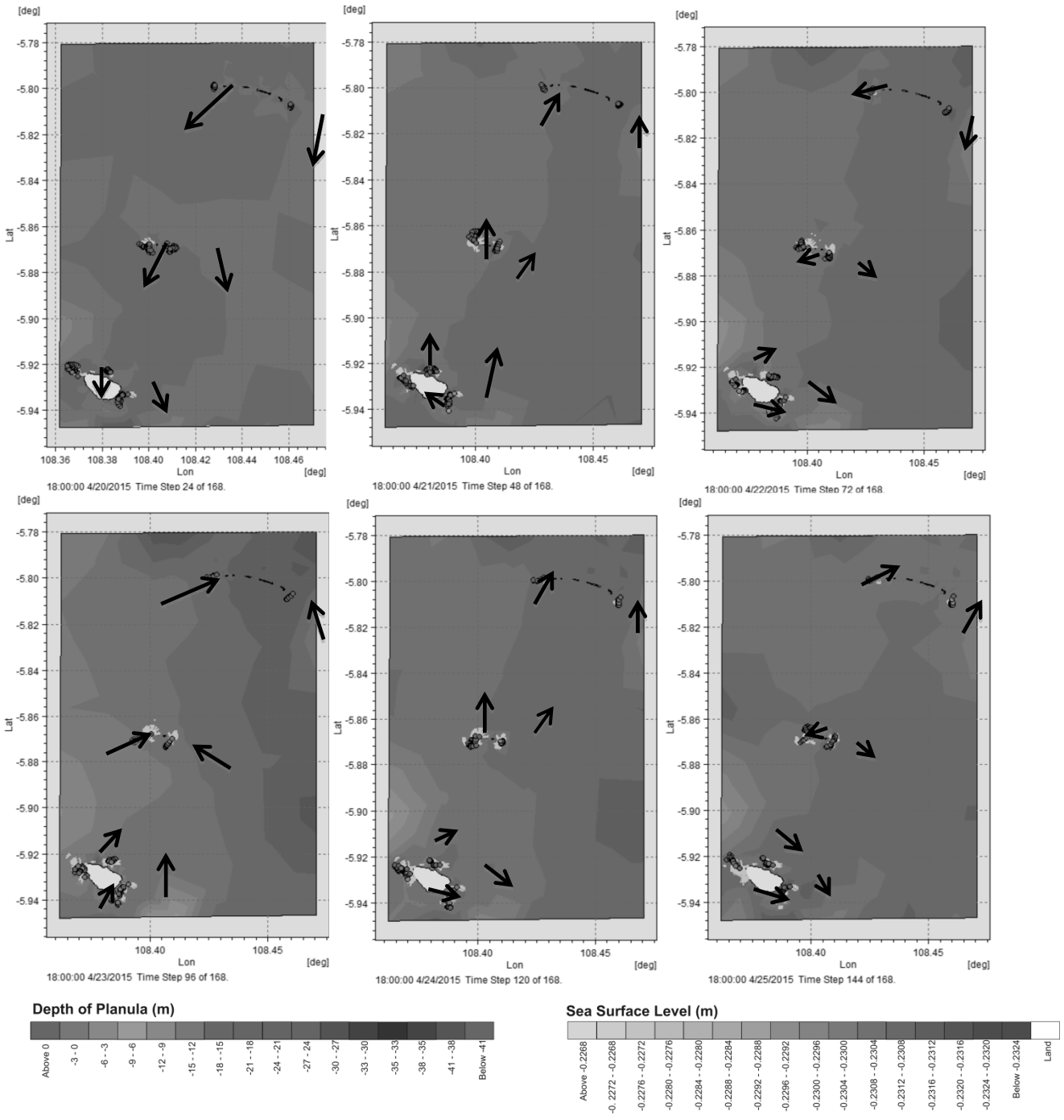

Figure 2. Planula dispersion in Biawak Islands, West Java, Indonesia

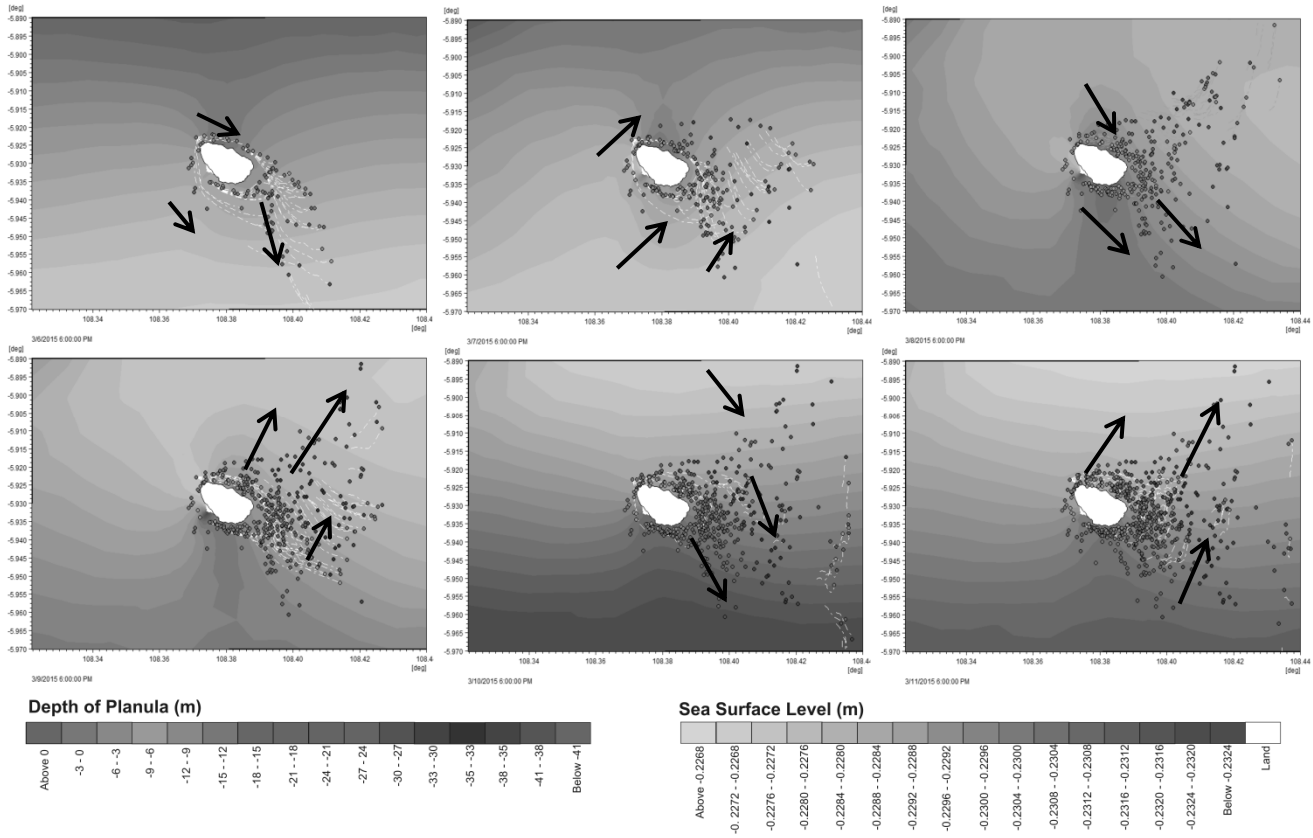

Figure 3. Planula dispersion on in Biawak Islands, West Java, Indonesia on March (the first 6 days after full moon)

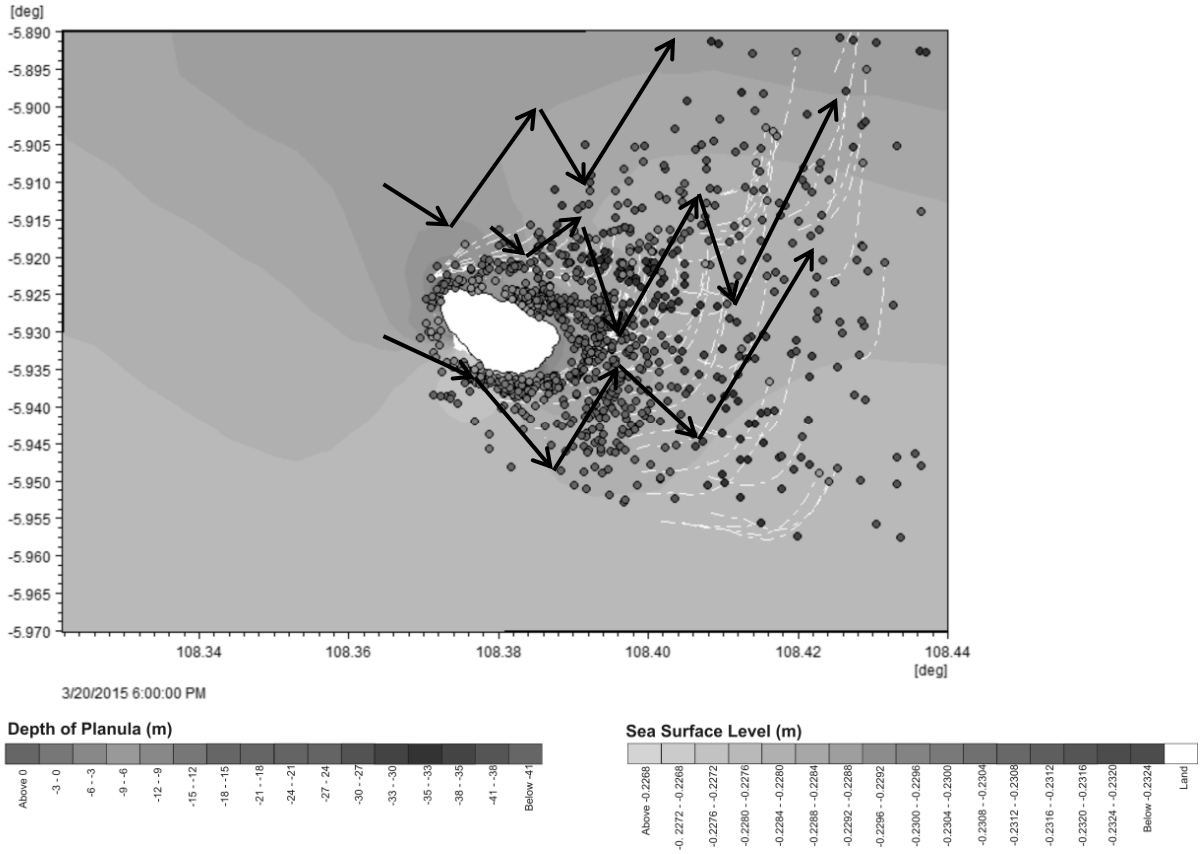

Figure 4. The overall planula dispersion movement on Biawak Islands, West Java, Indonesia

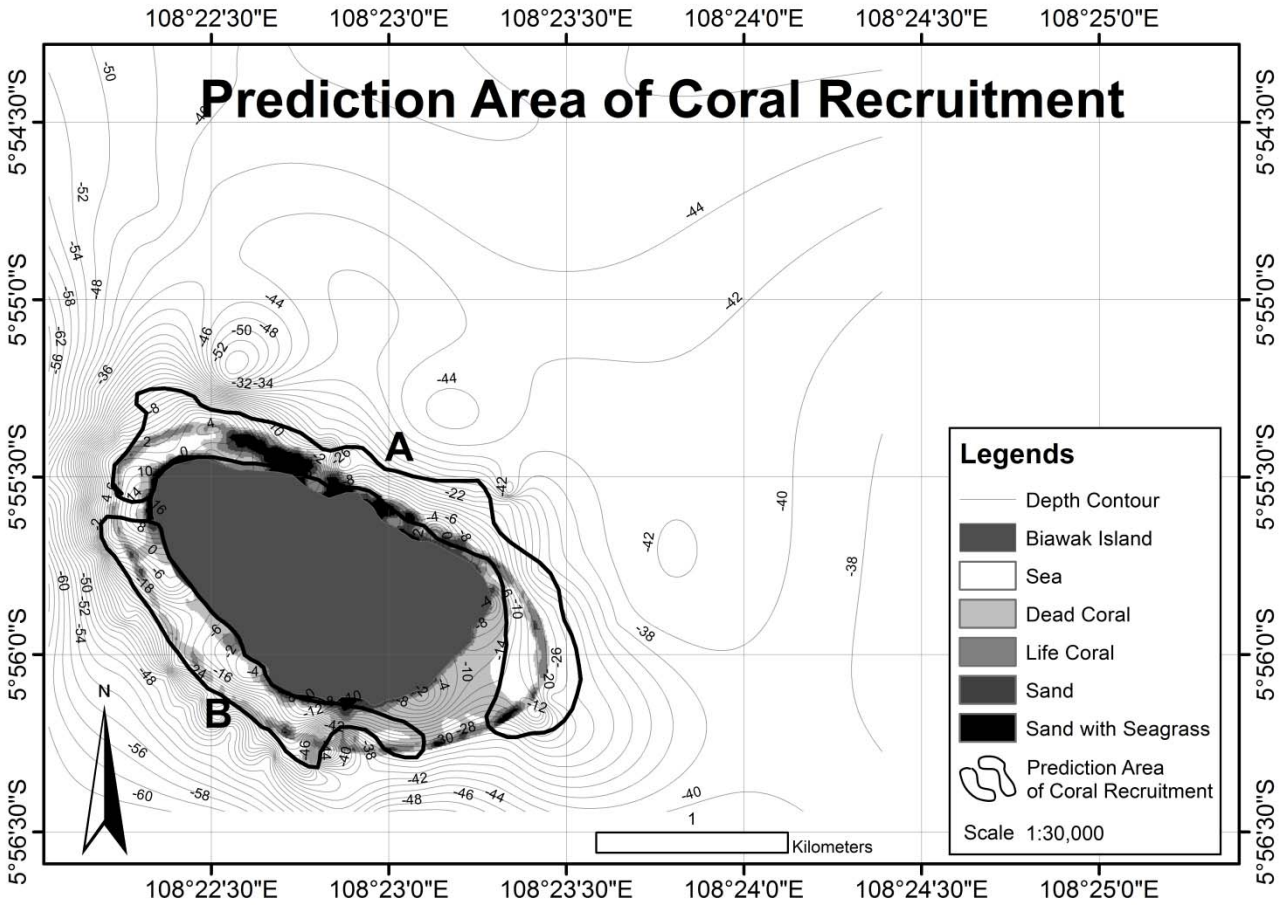

Figure 5. The Coral Recruitment Prediction Area on in Biawak Islands, West Java, Indonesia. A. in the north side and B. in the south

southeastern at a low ebb with the furthest movement of planula on the Biawak Island was 2.2 km. The furthest movement of planula on the Gosong Island was 1.66 km and planula dispersed to east and west region of Gosong Island. On the Cendikia Island, planula dispersed to northern and eastern with the furthest movement of planula on the Cendikia Island was 0.44 km, considering planula can wandering far away from their colony (Richmond 1985).

We did not incorporate biology and chemical factors in our model because we were interested in the hydrodynamics, the distance and pattern of planula dispersal to predict where planula settling and not the actual number of planula per species. Any evaluation of the results of this study should note the assumptions made in the model. Many factors can affect the number the dispersed including a number of gametes and planula, fertilization success and mortality rates. Mortality rates of planula dependent on numerous factors that include sedimentation (Gilmour 1999), water temperature (Nozawa and Harrison 2007), predation (Baird et al. 2001) and salinity (Vermeij et al. 2006), all of which complicate realized larvae settlement and recruitment. Coraline algae help planula to settle with inducing metamorphosis and paste planula to resembling a natural environment (Morse et al. 1996).

To informed decisions on how to effectively conserve the remainder Biawak Island's coral reef, it is necessary to determine planula dispersal movement among the northern to the eastern island because planula who derived from the northern and eastern part of the island dispersed to all around the island. Biawak Island has two coral recruitment prediction area, the area prediction A is 2.916 km² and for the area of prediction B is 1.614 km². The biggest area prediction apparent in the northern to eastern part the island where coral reef density was also high (Oscar et al. 2014).

ACKNOWLEDGEMENTS

We thank KOMITMEN Research Group for the persons who help collecting data over 2012-2015. The Data collected and data downloaded via PODC (Padjadjaran Oceanographic Data Centre). We also thankful for team survey over BIEXRE 1-2, TRAX 1, MYSEA, and ICSPACE Project. This research founded by DIKTI and UNPAD grants. We appreciate for the reviewer to make this paper more detail.

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