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Identification of coral recruitment in Lembongan Island, Nusa Penida, Bali

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Abstract. Coral recruitment is the increasing number of individual coral in reef ecosystems. Coral recruitment is generated from generative reproduction that produces coral planula and migration. The success of coral recruitment is determined by environmental factors. Coral recruitment beneficial are survived from environmental impact, maintaining the potential for recovery and reproduction. Lembongan Island coral reefs are categorized as fringing reef as coral reefs live along the coast and surround the island. Coral reef Lembongan Island is the main environmental carrying capacity for the life of this island. The research was conducted in Lembongan Island, Bali in 2015 until 2016. The research method is manta tow survey, line intercept transect and coral recruitment. Research shows the coral reef condition of Lembongan Island in medium to excellent category. Recruitment of coral attached to the substrate consists of Acropora millepora, A. palifera, A. tenuis, Fungia fungites, Montipora digitata, Pocillipora damicormis, Porites sp, Seriatophora hysterix, and Stylophora pistillata. The numbers of individual coral in 2015 are 63 individuals and in 2016 are 50 individuals.

1. Introduction

Lembongan Island coral reefs has a high value for people in this area. Coral reefs also provide millions of people with ecosystem services such as shoreline protection from wave action and erosion, generation of coralline sands, fisheries, tourism revenue, raw material for construction, raw natural products for pharmaceuticals, recreational and cultural values [1] [2]. Their total economic value has been estimated at $352,249 per hectare per year; higher than any other biome on earth [3].

Coral reef ecosystems comprise a complex array of habitats and communities that differ in biodiversity, ecological function, and associated organisms [4]. Most reefs are separated into distinct regions or zones that differ in topography, bottom type, and wave energy [5] [6].

Corals have sexual and asexual reproductive methods. Asexual reproduction is done by forming new shoots that will become a new individual on its parent. The formation of these shoots is done continuously which is a mechanism of increasing the size of the colony, but not forming new colonies.

Sexual reproduction is done by producing one of the sperm or egg to be released into the free waters. The egg will be equipped with a coelenterons that will be fertilized by sperm cells. This prose produces free-swimming planetary larvae, and will settle on the bottom or on hard subsets to form new colonies [7] [8] [9].
Corals can be hermaphrodite or dioeciously with an average of 7-10 years of sexual maturity. Conception will take place inside “the mother’s” gastro vascular chamber and the sperm released into the waters will enter this room. The eggs will be fertilized and held until they reach the stage of the larvae of the planula. The planula will be released and swimming in open water for an indefinite period, generally lasting several days or weeks to settle and start a new colony [8] [9].

Recruitment is the process by which young individuals (coral larvae) undergo larval settlement and become part of the adult population. Some species tend to settle close to their “mother colony”, others drift for great distances before settling down. Theoretical and empirical work has taught us that recruitment is influenced by a wide range of ecological processes such as competition, succession, facilitation, predation, and disturbance [10] [11].

Recruitment is an operational term and has been defined in several ways, but is commonly defined as when individuals become established in the local population [12] [13] [14]. Thus, recruitment combines both settlement and post-settlement Mortality prior to census. Recruitment is affected by different processes throughout the early life-history stages of an organism, and there are frequent trade-offs that influence success [15].

The environmental conditions that allow new individuals to colonize an area successfully and become established in the local population has been defined as an individual’s recruitment niche [10], similar to Grubb’s regeneration niche [16]. If the recruitment niche of an organism is parameterized according to its multiple environmental influences, trade-offs can be quantified and recruitment success predicted under multiple scenarios of biophysical forcing [17].

Theoretical and empirical work has taught us that recruitment is influenced by a wide range of ecological processes such as competition, succession, facilitation, predation, and disturbance [10, 11]. Demographic bottlenecks during recruitment can impact adult populations and occur in a variety of benthic organisms at different stages throughout early ontogeny [15] [18] [19] [20].

The rate, scale, and spatial structure of larval dispersal drive population replenishment, and therefore have significant implications for population dynamics, marine reserve orientation, and resilience of a system. The purpose of study was to know the species, abundance, and coral survival. The present study documented patterns of coral recruitment in Lembongan Island.

2. Theoretical Framework
Coral recruitment is a critical process that helps maintain coral populations and facilitates recovery after a disturbance [21] [22] [23]. Hard corals have a bipartite life cycle consisting of a pelagic dispersive larva and a sessile benthic adult stage. During this life cycle they pass through three demographic bottlenecks that influence coral recruitment: (1) larval supply, (2) settlement, and (3) post-settlement survival [24] [25].

Like most sessile marine invertebrates, scleractinian (reef-building) corals have a bipartite life history that involves a dispersive larval phase followed by settlement (i.e., attachment and metamorphosis) of minute individuals (≤1 mm) onto the reef substratum [13].

Coral larvae generally settle within several hours to weeks [26]. Certain larvae are competent to settle minutes after being released [27] [28], whereas others survive for over 244 days before settlement. While some larvae will settle close to their parent colony [29], others will be dispersed by currents and waves before they are ready to settle [30].

A consistently result in higher recruitment rates in this microhabitat nor does it reflect juvenile community structure in situ. When the distribution of coral recruits has been compared among microhabitats on the reef, they are usually found in higher abundances on exposed surfaces [31] [32] [33], rather than crevices [34] [35], creating an important and unresolved disparity between patterns of recruit distributions among microhabitats on settlement tiles and the reef [36].
3. Research methods
The research was conducted with the general condition began observations of coral reef ecosystems in the region by using the method of Manta Tow Survey. Manta Tow survey was conducted along the coast at intervals of 2 minutes were recorded on the percentage of coral cover from closing scoring system between live coral, dead and soft [37].

Manta Tow Survey data are analyzed and used a basis general condition of coral reefs mapping. This map will be used as the basis for determining the observation station of coral reefs with corals recruitment methods and Line Intercept Transect. Determination of research stations with randomly conducted with safety and represents the East, North, and West of Lembongan Island.

Line Intercept Transect method carried out to assess the benthic community based on the characteristics of life forms, especially the morphology of the coral reef community, so it can be known diversity of coral species in the area. Observations with Line Intercept Transect done by SCUBA diving at a depth of 3 m and 10 m [37]. Measurements were taken at two depths is assuming the two depths is considered to represent the condition of coral reefs because it usually grows well and a high diversity of coral species were also obtained at these depths.

Observation and identification of coral recruitment in accordance with English methods [37]. Observations were made at a depth of 5 meters, with 3 pieces of research racks on each research station. One unit that has a shelf research 24 pieces tile substrate placed at 4 different positions. Substrate has the size 10x10 cm with the manufacture of following the natural substrate reefs. Observations made with coral recruitment methods such as Figure 1.

4. Result and discussion

4.1. Coral reef ecosystem
Coral reef formation in Lembongan Island can be categorized as fringing reefs constituting the ones living along the beach and surrounding an island. The formation of coral reef surrounds Lembongan Island along the beach and surrounding an island.

Manta tow survey method result in North island of Lembongan Island had coral covering category between 4 - 5, it mean the life coral covering between 51 - 100 % (Figure 1).

Area residing in Tanjung Ental, Pura Sakenan until Tanjung Pemaroan represent area which high exploited as tourism area because their beauty and natural underwater view. Strong current in this area result coral covering species of branching, massive, and coral soft ware dominant. Sea weed farming activity conducted in this area from the beach until 3 meter deepness.

Coral reef condition in South Island of Lembongan Island had category between 1 - 3 with 0- 50 % for life coral covered. Sea weeds farming activity in Ceningan Strait to be depressing factor existence of coral reef in this area.

West part of Lembongan Island had life coral covering between 31% until 100% with category 3 until 5. This area represented as benefit tourism area, such as tourism activity and tourism accommodation. Besides exploiting for tourism this area also conducted by sea weed farming activity.
East part of Lembongan Island had life coral covering with category range from 3 - 5, with percentage between 31 - 100%. These areas represent Lembongan Island mangrove forest. Existence of mangrove in this area given double meaning to coral reef, one side mangrove protect coral reef from continent input and on the other when low tide substrate from the mangrove distributed to coral reef area. Sea weeds farming activity conducted by people in front of mangrove forest.

After observation with Manta Tow Survey, observation was done by using Line Intercept transect method.

Observations of November and 2015 and 2016 show the percentage of live coral cover at a depth of 3 meters ranging from 43.61 - 78.8% and depth of 10 meters between 43.61 - 78.8%. Research shows the coral reefs condition of Lembongan Island in medium to excellent category.
Height of live coral covering can be indication condition of environment supporting continuity coral reef in this area. Strong current bringing substrate as coral food also can be human being activity minimization function in coral reef Lembongan Island.

4.2. Coral recruitment
This studies use settlement tiles to quantify recruitment and the early dynamics of coral recruits. Settlement tiles have consistently been attributed to higher recruitment rates [38] [39] [40] [41]. It is also well established that coral larvae generally settle in much higher abundances on the cryptic undersides of flat settlement tiles [30] [42] [43].

Recruitment of coral attached to the substrate consists of Acropora millepora, A. palifera, A. tenuis, Fungia fungites, Montipora digitata, Pocillopora damicornis, Porites sp, Seriatophora hysterix, and Stylophora pistillata.

### Table 1. Coral Recruitment in Lembongan Island

| Species                  | Coral recruitment in November 2015 and 2016 | 2015 | 2016 | Site 2 | 2015 | 2016 | Site 3 | 2015 | 2016 | Site 4 | 2015 | 2016 |
|--------------------------|---------------------------------------------|------|------|-------|------|------|-------|------|------|-------|------|------|
| Acropora millepora       |                                             | 2    | 1    | 4     | 2    | 1    | 2     | 3    | 2    |       |      |      |
| Acropora palifera        |                                             | 2    | 2    | 1     | 2    | 2    |       | 2    |      |       |      |      |
| Acropora tenuis          |                                             | 2    | 1    | 1     | 1    | 2    | 1     | 2    | 2    |       |      |      |
| Fungia fungites          |                                             | 1    | 1    | 3     |      |      |       |      |      |       |      |      |
| Montipora digitata       |                                             | 3    | 3    | 4     | 3    | 1    | 2     | 2    | 2    |       |      |      |
| Pocillopora damicornis   |                                             | 3    | 2    | 1     | 1    | 2    | 2     | 3    | 1    |       |      |      |
| Porites sp               |                                             | 3    | 2    | 1     |      |      |       |      |      |       |      |      |
| Seriatophora hysterix    |                                             | 3    | 2    | 1     | 1    | 2    | 1     | 3    | 2    |       |      |      |
| Stylophora pistillata    |                                             | 1    | 2    | 2     | 2    | 1    | 1     | 2    | 1    |       |      |      |
| **TOTAL**                |                                             | 20   | 16   | 17    | 13   | 11   | 9     | 15   | 12   |       |      |      |
The number of available larvae for settlement larval supply therefore depends both on local larval availability and the number of larvae that arrive from more distant sources and is a combined result of reproduction, fecundity and larval dispersal [44].

Settlement refers to the metamorphosis process during which the coral larvae undergo morphological changes and attach to the substratum. Different cues can induce coral larvae to descend in the water column and start probing the benthos for a suitable nursery habitat [30].

The recruitment success throughout the earliest life-history stages of corals and uncover some intriguing trade-offs between growth, competition and predation, highlighting how these change and even reverse during ontogeny and under alternate disturbance regimes [45].

Recruits were categorised to each of the three major families Acroporidae, Pocilloporidae and Poritidae. The number of fecund adult corals and their reproductive output define larval production. Coral larvae travel on the water surface and have to survive a wall of mouths consisting of planktivorous fishes during the day and hard corals, zoanthids and anemones at night [46] [47].

The age of pocilloporid recruits with one polyp was determined by comparing their skeleton to skeletogenesis patterns [48]. Pocilloporid recruits of the age of 12 hours, 24 hours, 48 hours and 3 days or older could be identified. The Pocillopora damicornis recruits surveyed in each site, developed a second polyp after 11 to 15 days. Pocilloporid recruit size is constant during the first week after settlement and increases thereafter, supporting my result that a second polyp is formed after 11-15 days.

Porites sp constituted a majority of the small corals sampled within the plots, but only approximately 6 individual of the overall coral composition across the site. While P. porites has reportedly been a dominant recruiter in certain reef habitats [49], its congener P. astreoides, in addition to Agaricia spp. and Siderastrea siderea, more commonly dominate coral recruit assemblies in nearby Florida reefs [50] [51], as well as adult coral assemblages [52].

For a given supply of coral larvae, a suite of ecological interactions influence the success of coral recruitment and include: (1) settlement behavior and interactions with the substratum [30] [53]; (2) post-settlement Competition with algae and sessile invertebrates [54] [55]; and, (3) incidental and targeted predation from a variety of fish and mobile invertebrates [55] [56].

Reef formation in Lembongan Island can be categorized as fringing reefs constituting the ones living along the beach and surrounding an island. Conclusion research shows the coral reefs condition of Lembongan Island in medium to excellent category. Recruitment of coral attached to the substrate consists of Acropora millepora, A. palifera, A. tenuis, Fungia fungites, Montipora digitata, Pocillopora damicornis, Porites sp, Seriatopora hystrix, and Stylophora pistillata. The numbers of individual coral in 2015 are 63 individuals and in 2016 are 50 individuals.

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