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Original Paper

CORAL RECRUITMENT ON REEF BALL^{TM} MODULES AT THE BENETE BAY, SUMBAWA ISLAND, INDONESIA

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ABSTRACT

Reef Ball^{TM} structure is a popular artificial reef module that has been invested in many countries. Publication on its efficacy in promoting coral recruitment however remains lack of study or publication. This present study was aimed to examine the pattern of coral recruitment on reef ball structure at the Benete Bay of Sumbawa Island, Indonesia. Thirty reef-balls (dome shape; 0.90 cm height, 1.20 cm diameter) were monitored after three years of deployment. The results of this study showed that nearly all coral colonies grew on the outer vertical surface and upper side of the reef balls. The recruit number varied a lot between 1-76 colonies per module. Most recruits were belonged to the Family Acroporidae, which contributed approximately 76 percent to the whole recruitment (640 colonies). Branching acroporiid was the most abundant colonies (55%). Pocilloporidae and Faviidae both contributed approximately nine percent to the total recruitment, while Poritidae contributed about three percent. Other coral families only had <1% contribution. The diameter of coral colonies which were growing on the reef balls varied between 5-290 mm. The number of recruit on the ball was very low at 10 meter depth (1-5 colonies per ball) that was likely to be affected by sedimentation. This study showed that reef ball module can be effectively used as a method in rehabilitating damaged coral reefs, and developing a proto-reef.

Key words: proto reef, reef ball, coral, recruitment, restoration

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INTRODUCTION

Coral reef restoration and rehabilitation are increasingly important as global climate change might increase frequency of mass coral mortality due to bleaching (Hoegh-Guldberg, 1999) and diseases (Harvell *et al*., 2002; Jones *et al*., 2004). Reef Ball^{TM} has long been known as an intervention option in coral reef restoration or rehabilitation. In many situations owing to substrate instability or increasing sedimentation, damaged coral reefs are unable to naturally recover and restoration intervention is required. Introduction of reef ball or similar hard structures will provide additional substrate for coral larval settlement.

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Reef ball is also applied for promoting proto-reef, an ‘embryo’ of coral reef communities. When reef ball module is deployed on sandy substrate where coral normally does not grow, reef ball may serve as the first step-stone to establish coral reef communities. Coral settlement on the reef ball substrate will be followed by recruitment of following other marine invertebrates and coral reef fishes, as habitat complexity increases (Kaufman, 1983; Tomascik *et al*., 1996; Light and Jones, 1997).

Although reef ball has been used on over 4,000 projects in 55 different countries (Barber *et al*., 2008), publication on reef ball efficacy in promoting coral recruitment, however, is very few. Reports about reef ball study available on the internet are mostly about the early step on reef ball deployment reports, and research plans on the structures. The available scientific papers on reef ball efficacy are studies on fish population (e.g. Sherman *et al*., 2002; and Osenberg *et al*., 2002). There are no reports dealing about how well reef ball could promote the number of coral recruitment and how is the survivorship of recruits on reef ball structures. The present study is aimed at determining the efficacy of reef ball structure in promoting coral recruitment.

MATERIALS AND METHODS

Study site

Reef ball structures or modules studied are deployed by PT Newmont Nusa Tenggara (NNT), a copper and gold mining company, which is located at the Benete Bay of the Sumbawa Island, Indonesia (8^{O}54.2’S, 116^{O}44.5’E). The bay is facing westward to the Alas Strait, between the Sumbawa and Lombok Islands (**Fig. 1**). In the inner bay there are passenger and general cargo ports and a concentrate loading facility. All the reef balls studied were deployed on sandy substrates at about 4-12 m depth. This exposes them to high rate of sedimentation from tidal re-suspension of the sandy bottom substrate. Corals will not naturally grow on this location because lack of suitable substrate. Adjacent to this site, at the shallower southern coast corals naturally grow very well at 1-3 m depth.

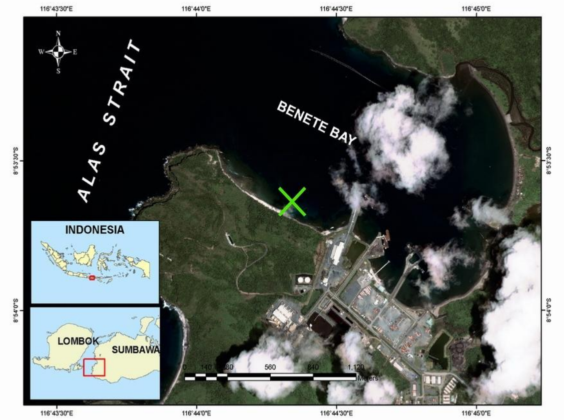

Fig 1: The Benete Bay, Sumbawa Island, Indonesia. Note X is location of the reef ball studied

Characteristics of reef ball

The present study was conducted on the big size reef ball: 0.90 cm height, 1.20 cm base diameter. It has approximately 7.0 m^2 surface area. At the time of study, March 2007, the total reef ball structure in the bay is 1037 modules. Measurements were done on reef balls that have been deployed for three years. Every year, there are about 300 reef balls deployed by PT NNT since 2004.

Sampling

Thirty (30) reef ball modules were haphazardly chosen at about 4-12 meter depths, as the samples of this study. For practical reason in finding the same unit of reef balls on future measurements, sampling was carried out on reef balls which are located at site surrounding the existing monitoring station. PT NNT has regular monitoring activities on reef ball module which is primarily taking measurement on benthic coverage at the structures.

Data collection was carried out *in situ* by two scuba divers. Collected data included coral genera (and species if possible), colony size, colony position on the module, and number of colony per module. All coral recruits >5 mm were counted and measured. Colony size was measured as the average of the longest diameter and its largest perpendicular diameter. Measurement was done using a caliper (Tricle Brand) with 0.02 mm precision. The caliper precision was likely to decrease to approximately 0.5 mm precision when it was used underwater with moderate tidal current.

RESULTS AND DISCUSSION

Number of coral colonies on the reef ball structures varied between 1-76 colonies per ball. After three years of deployment, total number of coral recruits counted on 30 structures were 640 colonies. Mean number of coral colonies (±1SD) per module was 22.33±18.84 colonies. Most coral colonies occupied the outer surface of the reef ball. At reef balls with clean surfaces, the top side was also crowded with coral colonies. Among depth spectrum, the number of coral recruits was very much lower at deeper waters (10-12 m) than at middle (7-9 m) and shallow (3-6 m) waters (F=3.37, P<0.05, df=2,26). Between the last two depth ranges, the average number of coral recruits was about the same (**Fig. 2**). Reef ball at deeper waters had more sediments trapped on epilithical algae growing on its surface. On many occasions sediment cover reached >10 mm thick.

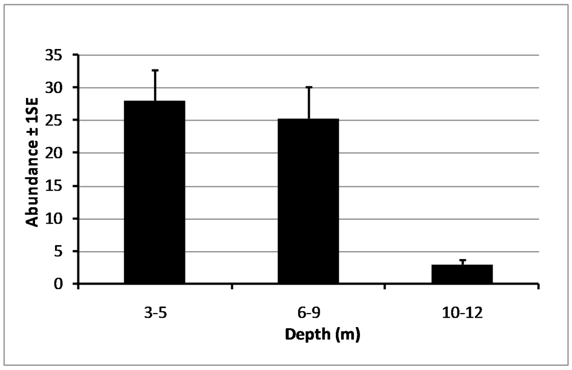

Fig 2: Comparison of coral colony abundance among three depth ranges.

Results of this study showed that reef ball structure could effectively promote coral recruitment and therefore is potentially effective for coral reef restoration or rehabilitation. Since reef ball deployment on this study was aimed to promote a proto reef, it is likely that the proto reef could be achieved by this method, at least on 4-10 m depths. Introduction of artificial substrates to promote coral recruitment had been reported previously by several authors (Clark and Edwards, 1995; Thongtham and Chansang, 1999; Bachtiar, 2000; Fox *et al*., 2005). On sandy substrate in which natural coral cannot grow, the introduction of reef balls module will definitely provide suitable substrate for coral larvae to settle and grow on the substrate.

At present, difference of reef ball's efficacy from other structures has not been known yet quantitatively. Reef ball structure was more developed than ordinary concrete modules. Silica was added onto composition of reef ball module. Micro surface of the reef ball module was also increased by roughened its surface at the end of construction process. Thus it was expected that reef ball may serve as better substrate for coral recruitment. Difference of reef balls efficacies in promoting coral recruitment between locations showed that reef balls modules at the Benete Bay had more coral colonies than those in Mexico. Average number of coral colonies on this study was approximately 22 colonies per reef ball module, while a similar study in Mexico reported only 13 colonies per reef ball module (Kilfoyle *et al*., 2008).

The number of recruits was lower at 9-12 m depth than at shallower waters. There are three possible explanations about this finding. Firstly, larval abundance (larval supply) was lower at deeper waters than on shallower sites. Secondly, planullae settlement was lower at deeper waters. Lastly, post-settlement survival was lower at deeper waters. Among the three explanations, the last two hypotheses are likely the most probable explanations. The main reason for this low settlement and low survival is due to higher sedimentation.

Sedimentation occurring on the Benete Bay was mainly from bottom-sediment resuspension by tidal currents. Field observation showed that water turbulence during tidal current brings about sediment resuspension. As proportion of fine sediment was higher at deeper waters, intensity of sediment resuspension was also higher at this site. Sediment trapped in epilithical algae prevented coral planullae to settle on the reef ball surface. The sediment might also burry and kill coral recruits that reduced its survivorship. At present study, there was no available sedimentation data on the Benete Bay. The sedimentation hypothesis needs to be clarified in future study.

Taxa of coral colonies were predominated by Acroporiidae. Most coral colonies growing on the reef ball were belong to Acroporidae which contributes 75.78% of the total recruitment (**Fig 3**).

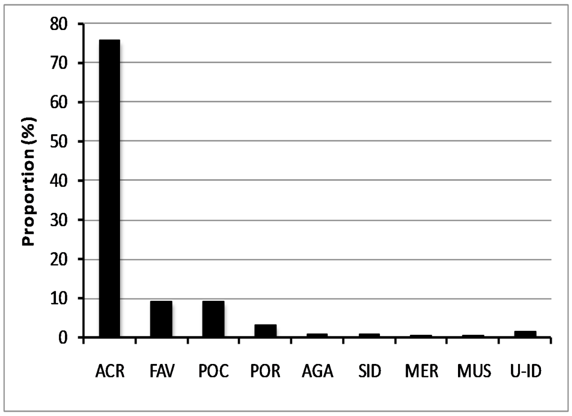

Fig 3: Composition of coral communities on reef ball structures. ACR= Acroporidae, FAV= Favidae, POC= Pocilloporidae, POR= Poritidae, AGA= Agaricidae, SID= Siderateridae, MER= Merullinidae, MUS= Musidae, UID= unidentified.

Other contributing coral families on recruitment at the reef ball structures were Faviidae (9.22%), Pocilloporidae (9.22%) and Poritidae (3.12%). The other coral families had proportion of <1%. The mean (±1SD) of acropriid abundance was 16.17±17.74 colonies per unit reef ball.

Among the Acroporidae approximately 93% colonies were belong to genera *Acropora*, while the rest belonged to *Montipora* (7%) and *Astreopora*. (0.04%). From the total of 450 acroporiid colonies, 73% colonies were the branching *Acropora*. The predominant coral recruits were *Acropora divaricata* and *A. loripes*. Non-acroporiid corals were mostly Faviidae and Pocilloporidae. Among the 54 colonies of Faviidae, 50% are *Favites.* The genera of *Goniastrea* and *Platygyra* contributed about 22% and 11% respectively. Other genera *Echinopora*, *Montastrea* and *Favia* all shared the same proportion, approximately 6%. The family of Pocilloporidae was represented by three genera from 59 colonies. Among this family, *Pocillopora* was the most abundant genera (53%), followed by *Stylopora* (24%) and *Seriatopora* (23%).

The predominance of Acroporidae colonies has been reported on previous study in the eastern Lombok Strait, Indonesia (Bachtiar, 2003). This finding, however, differs from several previous reports in other Indonesian Seas that coral recruitment is predominated by Pocilloporidae, for example the Karimunjawa National Park (Munasik pers. com.), and Komodo National Park waters (Fox *et al.*, 2005). The predominance of Acroporidae supports a hypothesis that coral recruits mostly come from a long distance larvae source. In adjacent coral reefs at the Benete Bay, abundance of natural Acroporiid colonies was very small. At species level, taxa of coral recruits were also very much different from natural colonies on the bay. Tabulate- or plate-form colonies of *Acropora solitaryensis* and *A. efflorescens* growing on reef balls are rarely found on natural reefs in the Lombok waters and Alas Straits (personal observation). Corals *A. solitaryensis* is reported occupy southern coast of Indonesia (Indian Ocean) (Suharsono, 2008), while *A. efflorescens* is not yet reported in Indonesian coral reef literatures (Wallace and Wolstenholme, 1998; Suharsono, 2008). These suggest therefore that coral recruitment on the reef ball module is likely from Indian Ocean waters. This finding is very much different from a recruitment study on Maiton Island, Thailand, that most coral recruitment on concrete module is predominated by Poritidae, a predominant local population corals (Changsang *et al.*, 2008). It is likely that coral recruitment on a concrete module is very site specific, without any general patterns.

The present study also showed that coral colonies growing on the reef ball structure very much varied in size, between 5-290 mm. Mean colony size (±1SD) was 60.74±45.88 mm. Large colony size (>100 mm) was found in the families of Acroporidae and Pocilloporidae. Comparing colony size among Acroporidae showed that *Acropora* tabulate (ACT) had the largest average colony size (99.98±7.52 mm). ANOVA was not applied on this comparison as the number of sample varies from 2 to 355 recruits. On **Fig. 4**, colony size of branching Acropora (ACB) could be underestimated as the measurement used colony diameter.

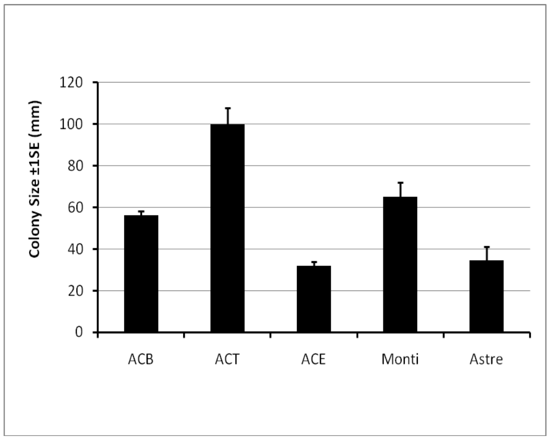

Fig 4: Comparison of colony size (diameter) among acroporiid colonies. ACB= branching *Acropora*, ACT= tabulate *Acropora*, ACE= encrusting *Acropora*, Monti= *Montipora* spp., Astre= *Astreopora* spp

The size of coral colonies found at the reef balls may indicate that they grew at about the same rate as in natural reefs. Three years after deployment the largest colony diameter was 290 mm. This size is about the same as reported in the Komodo National Park (Fox *et al.*, 2005). Large colony size was found mostly in Acroporiidae. It could mean that these colonies grew faster or they colonized the reef ball earlier, or both of them. The coral Acroporidae has been known to grow very fast, while Pocilloporidae is the best colonizers, particularly *Seriatopora*. Surprisingly, there were not many *Seriatopora* colonies growing on the reef ball.

The present study showed that reef ball is a good method for promoting proto reef, coral reef restoration and rehabilitation. There are several other artificial reefs, however, available to be used in coral reef restoration or rehabilitation. Razak (2008) reported that Ecoreef® module is a good method for promoting coral recolonization on a damaged reef at Manado, Indonesia. Maekouchi et al. (2008) provided convincing evidences that Eco-block used in port breakwaters is a very suitable substrate for coral colonization, at Okinawa, Japan. Seventeen years after deployment, nearly all Eco-block modules are covered by coral colonies. These studies provide additional alternative methods in promoting coral recruitment. Some of them may be used for developing a proto reef as the reef ball in the present study.

CONCLUSION

Reef ball module was proven effective as a restoration and rehabilitation methods in coral reef management. It is very likely, however, that any suitable materials for coral settlement can be used well in coral reef restoration. As long as larval abundance is high and water quality is good, corals can settle well on any suitable substrates. It may include concrete modules, volcanic stones and other hard substrates. In developing a proto reef, sedimentation effect from tidal resuspension should be taken into account as the most serious hazard when other water quality parameters are in good condition.

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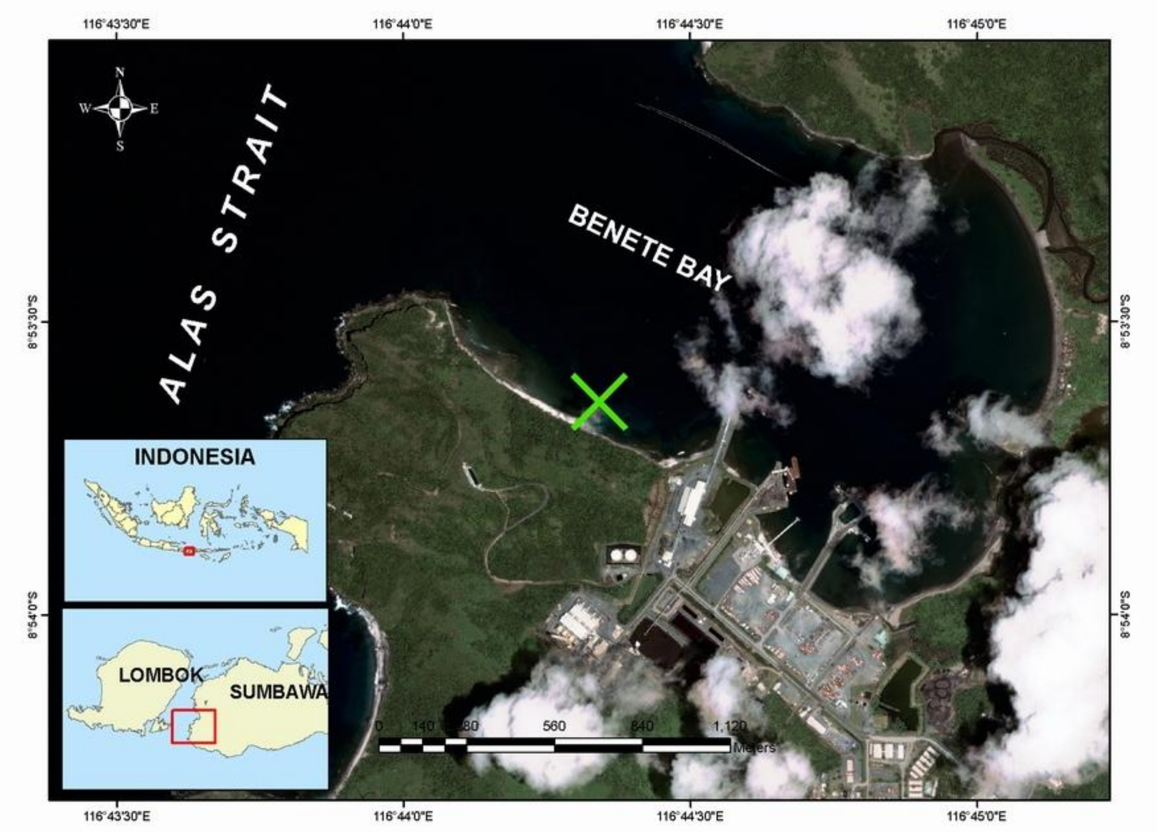

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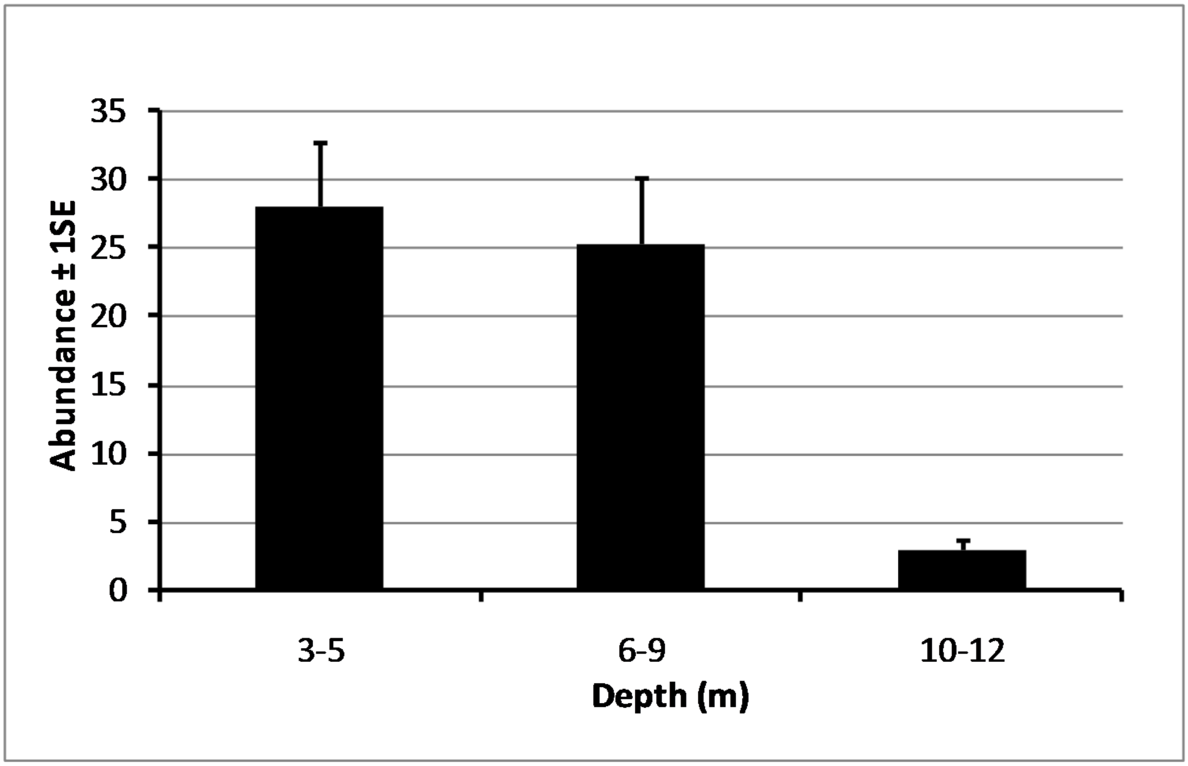

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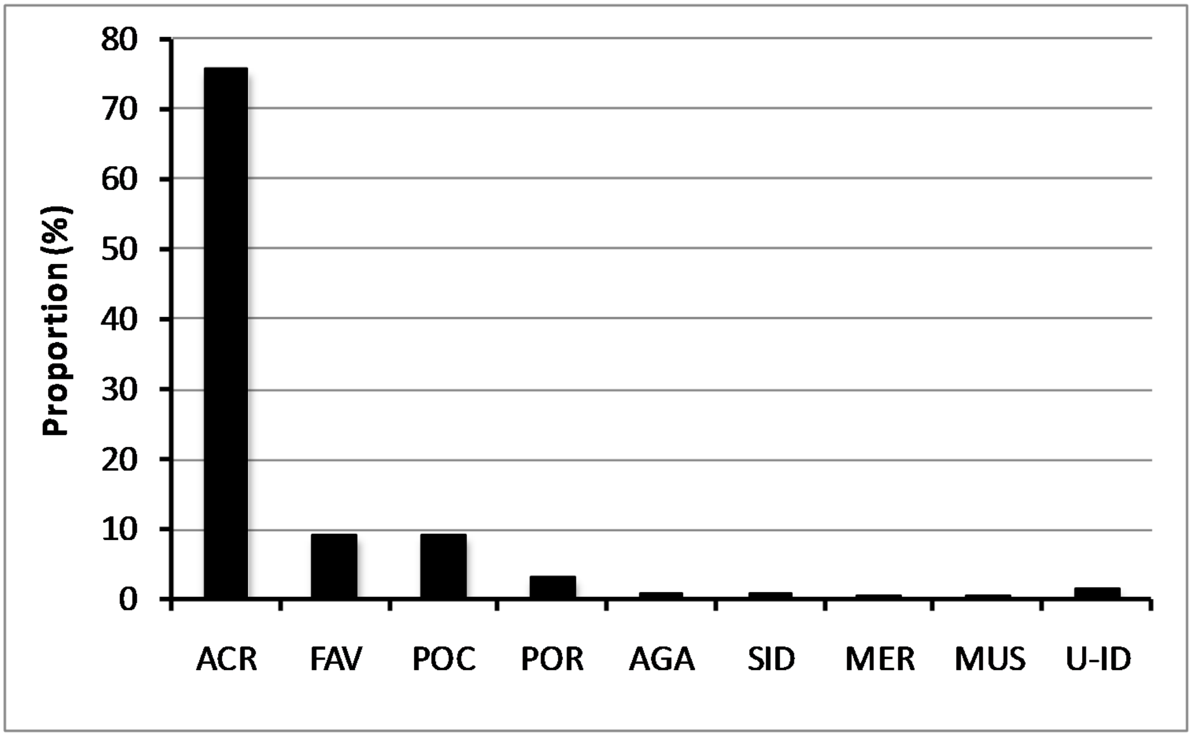

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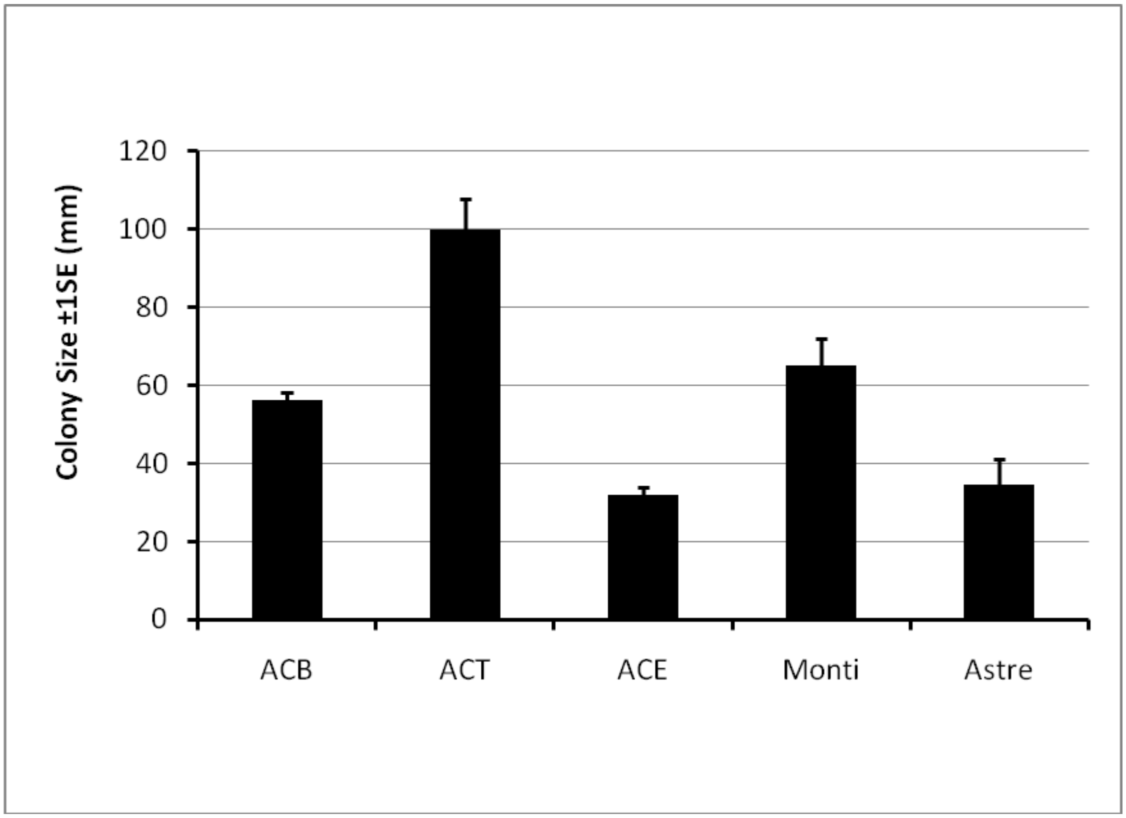

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