INFLUENCE OF MINERAL ACCRETION INDUCED BY ELECTRIC CURRENT ON THE SETTLEMENT AND GROWTH OF THE SCLERACTINIAN CORAL *POCILLOPORA DAMICORNIS* (CNIDARIA, ANTHOZOA, HEXACORALLIA)

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ABSTRACT

The effect of mineral accretion induced by electric current on settlement, growth, and survival of planula larvae and juvenile corals of *Pocillopora damicornis* was examined by both laboratory and field experiments. The laboratory experiment showed that the numbers of larvae settling on tiles with coralline algae and steel plates encrusted with limestone under no electric current condition were higher than that of other conditions. In the field, the highest survival rates of juvenile corals occurred under the lowest electric current density. However, there was no difference on the growth of juvenile corals between different electric current levels. The mineral accretion could potentially be used to enhance survival of juvenile corals for coral rehabilitation purpose.

Keywords*:* electric current, mineral accretion, growth, survival, Thailand.

INTRODUCTION

Coral reefs around the world have been declined due to natural phenomenon and anthropogenic disturbances recently (Bruno et al., 2007; Burke et al., 2011). In Thailand, changes on diversity and cover of reefs have been attributed by both direct and indirect impact of disturbances. The examples of disturbances include increasing seawater temperatures, tsunami, pollution, illegal fishing, anchor damage, sedimentation and invasion of non-native species (Brown, 1997; Chavanich et al*.*, 2005; 2009a; 2009b; Wilkinson, 2008). To restore the degraded reefs, now several techniques have been employed (Edwards and Gomez, 2007).

One of the coral restoration techniques that have been introduced to Thailand is mineral accretion through electrolysis in seawater (Hilbertz and Goreau, 1996; www.biorock.net). This technique has been developed in 1974 by a German architect and marine scientist, Wolf H. Hilbertz (www.biorock.net). A structure induced under low electric current forms a carbonate substrate, which later serves as a substrate for settlement and survival of marine organisms (www.biorock.net). However, the potential use of this technique for coral restoration is still not fully experimented under different environmental conditions, and the results of the technique seem to be varied depending on location, coral species and how experiments are conducted (Borell et al., 2010; Goreau et al., 2004; Sabater and Yap, 2002; 2004; Schuhmacher et al., 2000; Stromberg et al*.*, 2010). Biorock® Technology Thailand was established since 2004, and operates as a non-profit group (Thongtham, 2009; www.biorock-thailand.com). In 2005, the group starts coral reef restoration project at Koh Samui, Surat Thani Province through the support from a local government and private groups by constructed metal structures at several reefs (Thongtham, 2009). Then, a low voltage of electric current is applied through the metal frames resulting a composition of limestone and brucite $CaCO_3$ (Thongtham, 2009; www.biorock-thailand.com).

At present, there are some scientific studies related to a mineral accretion technology for reef restoration (Borell et al., 2010; Goreau et al., 2004; Sabater and Yap, 2002; 2004; Schuhmacher et al., 2000; Stromberg et al., 2010; van Treeck and Schuhmacher, 1997). However, none is conducted in Thai reefs. The purpose of this study was 1) to examine the effect of electric current and electrochemical deposition of $CaCO_3$ on settlement of larvae of *Pocillopora damicornis* (Linnaeus, 1758, and 2) to determine the influence of different levels of electric current densities on the growth and survival of the juvenile *P. damicornis* in the field.

MATERIAL AND METHODS

Both laboratory and field experiments were conducted. The laboratory experiment was performed at the coral hatchery at Samesan Island, upper Gulf of Thailand, Chonburi Province, while the field experiment was operated at Koh Samui, middle Gulf of Thailand. At Koh Samui, mineral accretion technology had been used to restore reefs in the area. Experimental metal structures for the field study were constructed with the assistance from Biorock® Technology Thailand.

Laboratory experiment on the settlement of coral larvae

There were 3 types of substrates (10x10 cm in size) used in the experiment: steel plate, steel plate encrusted with limestone and clay tile with coralline algae. Each type of substrates consisted of 4 treatments: plate with 4 A/m^2 electric current density, plate with 2 A/m^2 electric current density, plate with no electric current density but hooked with the electric current equipment and plate with no electric current and not hooked with the electric current equipment as control. Each treatment had three replicates, each of which contained 200 individuals of planula larvae of *P. damicornis.* Separated aquarium tanks (20x20x20 cm) were applied for each treatment. In the experiment, natural sea water from the sea was used, and the average sea water temperature during the experiment was 28°C. At the beginning of the experiment, 200 larvae were released into each aquarium in each treatment. Then, after 24 hours of the experimental trial, the numbers of larvae settling on each plate were counted. A one way ANOVA test followed by Tukey's pairwise mean comparison was performed to examine differences in number of settling larvae in each type of substrates.

Field experiment on growth and survival of juvenile corals

Four metal structures which were build by Biorock® Technology Thailand 1–2 years prior to the experiment was used in this study. The structures were located on a reef 200 meters from Chaweng Beach, Koh Samui at approximately 7 m depth of water. The size of the structure was 320X340X160 cm. Each of 3 electric current density levels (0.4, 0.65, 0.9 A/m^2) was assigned in each metal structure. The fourth metal structure was a control with no current density. However, no juvenile corals were observed settling on the forth metal structure. Thus, the monitoring of juvenile corals in the forth structure was not possible. The experiment was conducted in 4 months from June to October 2008. In each structure, at the beginning of the field experiment, 10 newly natural recruiting juvenile corals of *P. damicornis* (between 0.4–2.4 cm in diameter) were randomly selected and tagged for monthly monitoring the growth and survival rates. The maximum width of juvenile coral colonies was measured. A one way ANOVA test followed by Tukey's pairwise mean comparison was performed to examine differences in growth and survival rates of corals in each type of metal structures.

RESULTS

The results from the laboratory showed that there were significant differences on the settlement of *P. damicornis* larvae on different electric current density and different types of plates ($P<0.05$). Control groups on the tile with coralline algae and steel plate encrusted with limestone had the highest numbers of settling larvae (Fig. 1). However, no significant difference was found in the percentage of larvae settling on different plates under different current density treatments (Figure 1).

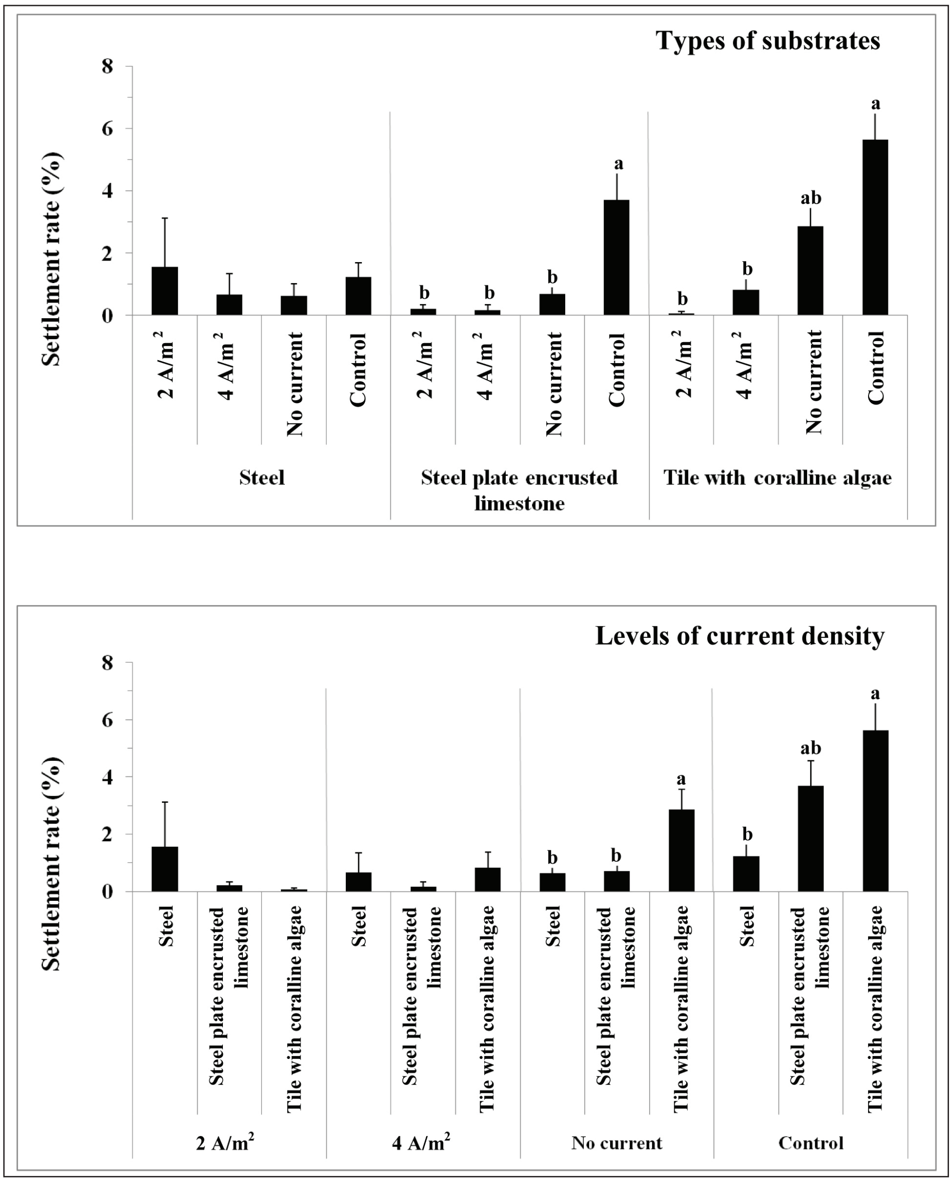

Figure 1. Settlement rates of *Pocillopora damicornis* planula larvae on different types of plates under different electric current density levels shown by types of substrates (above) and shown by levels of current density (below). Mean and SE are shown by bars and lines respectively. Significant difference ($P < 0.05$) in settlement rates is designated by different letters (a and b) above each bar.

The field experiment showed that there was no difference on the growth rate of juvenile *P. damicornis* between different levels of electric current density (Figure 2). However, after 4 months, the juvenile corals under the lowest current density showed the highest survival rate (50%), followed by one under the medium current density (42%). The juvenile corals under the highest current density showed the lowest survival rate (11%) (Figure 3).

DISCUSSION

The laboratory results showed that the settlement of *P. damicornis* larvae differed significantly between different electric current densities and different types of plates. Coral larvae tended to settle more on the tile with coralline algae and on the steel plate encrusted with limestone under no electric current density than ones under current density. However, it has been reported that the mineral accretion enhanced the recruitment of

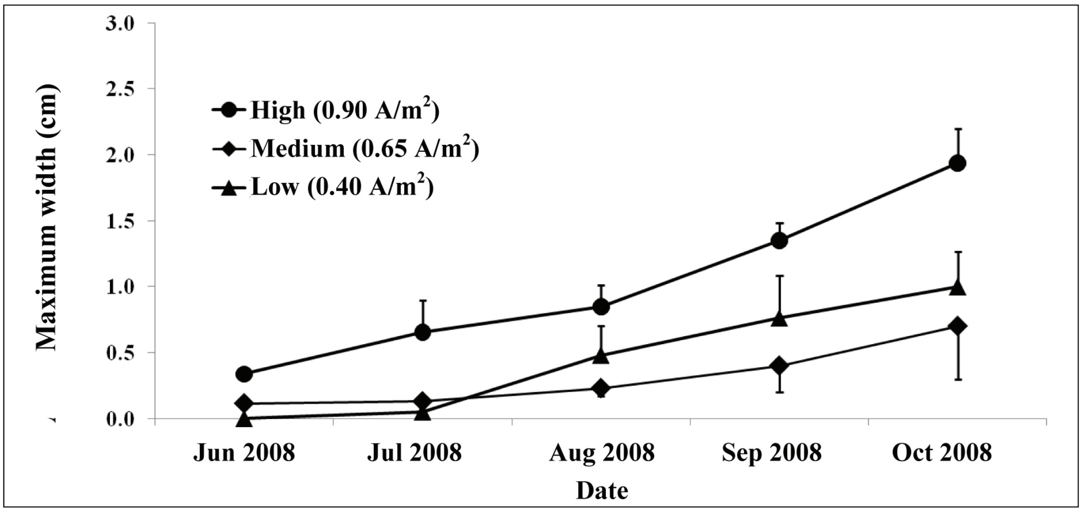

Figure 2. Maximum width of juvenile *Pocillopora damicornis* growing under three different levels of electric current densities during the 4-month period. Mean and SE are shown.

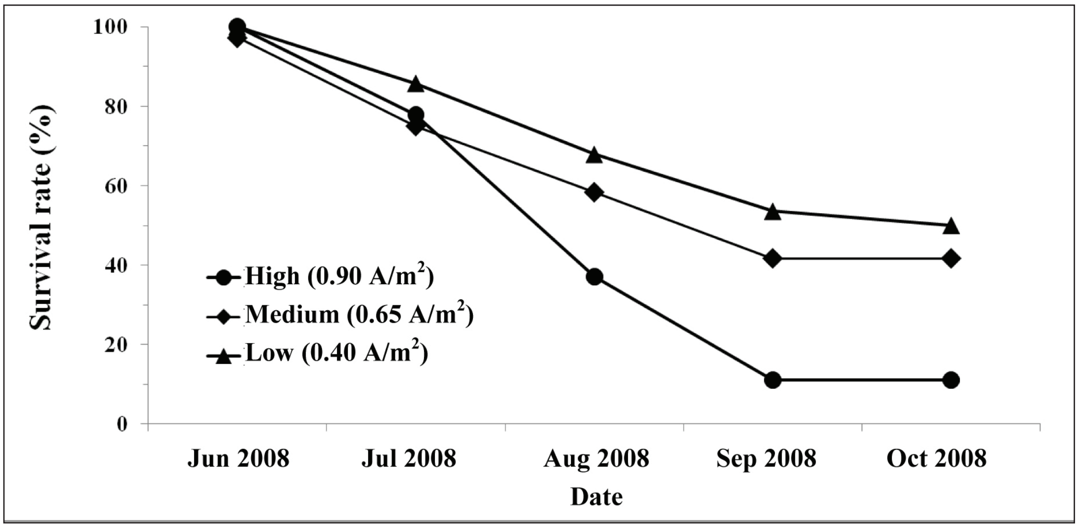

Figure 3. Survival rate of juvenile *Pocillopora damicornis* growing under three different levels of electric current densities during the 4-month period.

calcareous organisms and eliminated fleshy algae by burial under the mineral deposition or by pH increase (Schuhmacher and Schillak, 1994).

In this study, no difference on the coral growth under different levels of electric current density was observed. The studies of Romatzki (2008) and Stromberg et al. (2010) showed that the corals *Acropora yonge, A. pulchra*, and *Lophelia pertusa,* under low current density grew higher than that of in the higher current density. However, the growth rate in this study was not as high as that on the mineral accretion under a restoration program (www.biorock.net). It reported that the corals on the mineral accretion grew two to six times higher than natural reefs (www.biorock.net), but no study has confirmed this so far.

In the field experiment in this study, high survival of juvenile corals was recorded in the lowest electric current density, and high current density was not good for the survival. Stromberg et al. (2010) pointed that the positive effect on the survival of corals was restricted to the lowest current density, and overcharging of current density may reduce survival and growth of corals.

In conclusion, the results from this study showed high survival of juvenile corals under the low electric current density while the settlement and the growth of juvenile corals did not show significant benefit under the electric current condition. Many works have reported that the mineral accretion technology can enhance and improve coral recruitment, growth, and survival for coral restoration and rehabilitation (Borell et al., 2010; Goreau et al., 2004; Romatzki, 2008; Sabater and Yap, 2002; 2004; Schuhmacher et al., 2000; Stromberg et al., 2010; in this study). However, the data from the previous studies and this study still showed inconsistency of the results when compared with the results from the restoration programs claimed by the technology. This may be due to several reasons, for example, conditions of experimented corals, coral species, experimented locations and experimental designs. More elaborate studies are needed to understand the relationship and mechanisms between mineral accretion and corals, which could later apply for a maximum use of this technique for coral restoration and rehabilitation purpose.

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REFERENCES

Borell, E.M., S.B.C. Romatzki and S.C.A. Ferse. 2010. Differential physiological responses of two congeneric scleractinian corals to mineral accretion and an electrical field. Coral Reefs, 29: 191–200.

Brown, B. E. 1997. Coral bleaching: causes and consequences. Coral Reefs, 16: S129–S138.

Bruno, J. F., E.R. Selig, K.S. Casey, C.A. Page, B.L. Willis, C.D. Harvell, H. Sweatman and A.M. Melendy. 2007. Thermal stress and coral cover as drivers of coral disease outbreaks. PLOS Biology, 5: e124.

Burke, L., K. Reytar, M. Spalding and A. Perry. 2011. Reefs at risk revisited. World Resources Institute, Washington. 130 pp.

Chavanich, S., A. Siripong, P. Sojisuporn and P. Menasveta. 2005. Impact of Tsunami on the seafloor and corals in Thailand. Coral Reefs, 24: 535.

Chavanich, S., V. Viyakarn, T. Loyjiw, P. Pattaratamrong and A. Chankong. 2009a. Mass bleaching of soft coral, *Sarcophyton* sp. in Thailand and the role of temperature and salinity stress. ICES J. Mar. Sci., 66: 1515–1519.

Chavanich, S., V. Viyakarn, S. Piyatiratitivorakul, K. Suwanborirux and S. Bussarawit. 2009b. Introduced tunicate species in Thailand. Aquatic Invasions, 4: 349–351.

Edwards, A.J. and E.D. Gomez. 2007. Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty. Coral Reef Targeted Research & Capacity Building for Management Programme: St Lucia, Australia. 38 pp.

Goreau, T.J., J.M. Cervino and R. Pollina. 2004. Increased zooxanthellae numbers and mitotic index in electrically stimulated corals. Symbiosis, 37: 107–120.

Hilbertz, W.H. and T.J. Goreau. 1996. A method of enhancing the growth of aquatic organisms, and structures created thereby, U.S. patent number 5, 543, 034.

Romatzki, S. 2008. Reproduction strategies of stony corals (Scleractinia) in an equatorial, Indonesian coral reef. Contributions for the reef-restoration. Ph.D. dissertation. University of Bremen, 110 pp.

Sabater, M.G. and H.T. Yap. 2002. Growth and survival of coral transplants with and without electrochemical deposition of $CaCO_3$. J. Exp. Mar. Biol. Ecol., 272: 131–146.

Sabater, M.G. and H.T. Yap. 2004. Long-term effects of induced mineral accretion on growth, survival and corallite properties of Porites cylindrica Dana. J. Exp. Mar. Biol. Ecol., 311: 355–374.

Schuhmacher, H. and L. Schillak. 1994. Integrated electrochemical and biogenic deposition of hard material: a nature-like colonization substrate. Bull. Mar. Sci, 55: 672–679.

Schuhmacher, H., P. van Treeck, M. Eisinger and M. Paster. 2000. Transplantation of Coral fragments from ship groundings on electrochemically formed reef structures. Proceedings 9th International Coral Reef Symposium, Bali, Indonesia 2, pp. 983–990.

Stromberg, S.M., T. Lundalv and T.J. Goreu. 2010. Suitability of mineral accretion as a rehabilitation method for cold-water coral reefs. J. Exp. Mar. Biol. Ecol., 395: 153–161.

Thongtham, N. 2009. Rehabilitation of coral reefs in Thailand. Phuket Marine Biological Center, Department of Marine and Coastal Resources, 64 pp. (in Thai)

van Treeck, P. and H. Schuhmacher. 1997. Initial survival of coral nubbins transplanted by a new coral transplantation technology - options for reef rehabilitation. Mar. Ecol. Prog. Ser., 150: 287–292.

Wilkinson, C. 2008. Status of coral reefs of the world. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia, 296 pp.