



Coral Diversity at Losin Pinnacle, an Offshore Reef in the Gulf of Thailand: Toward a Future MPA

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Severe coral bleaching events in the Gulf of Thailand and along the Andaman Sea coast of Thailand caused widespread coral mortality in 1998 and 2010. The consequent decrease in coral populations impacted the structure, health, and services of Thai coral reefs. However, most colonies in the offshore reef of Losin were still alive after the coral bleaching events. Therefore, this study was conducted by the Department of Marine and Coastal Resources in order to help to establish a proposal for making it a Marine Protected Area (MPA). Surveys on coral diversity were conducted to produce a checklist of reef-building corals. Seventy-six coral species were found, with the most dominant species being *Porites lutea* and *Acropora* communities, such as *A. intermedia*, *A. grandis*, *A. muricata*, *A. cytherea*, and *A. valenciennesi*. This area is expected to be designated as a restricted MPA area, under the “Act on the Promotion of Marine and Coastal Resources Management B.E. 2558 (2015).” The high diversity of hard corals discovered in this study assists in promoting an Announcement of the Losin Marine and Coastal Resources Protected Areas following Ministerial Regulation.

Keywords: *Acropora*, coral bleaching, protected area, management, Gulf of Thailand

INTRODUCTION

Coral reefs are one of the most vulnerable marine ecosystems to elevated sea temperature, and this has resulted in global coral bleaching (Moss et al., 2010; Hoegh-Guldberg, 2011; Burke et al., 2012; Kennedy et al., 2013; Graham et al., 2015; Hughes et al., 2017; Gintert et al., 2018). Predictions of annual coral bleaching occurring in the next 30 years are alarming due to the likelihood of increased frequency and severity (Manzello, 2015; Hughes et al., 2017). Increased coral bleaching and thermal stress impact hard coral species differently, with some species suffering significantly more mortality than others (Guest et al., 2012; Wooldridge, 2014). Thermal stress has not only been a concern for susceptible corals but is also a threat to coral reef health in terms of coral diseases (Gintert et al., 2018). Temperature-stressed corals could be more susceptible to opportunistic pathogens, which may be associated with subsequent diseases (Precht et al., 2016; Raymundo et al., 2018).

Widespread coral mortality from mass coral bleaching events between 1998 and 2010 in Thai waters has been reported previously (Yeemin et al., 2009; Phongsuwan and Chansang, 2012;

Sutthacheep et al., 2013; Yucharoen et al., 2015). Coral reefs along the Gulf of Thailand experienced high mortality, and a subsequent loss of *Acropora* species was reported in the region (Yeemin et al., 2009; Hoeksema et al., 2013). High losses of *Acropora* corals from these reefs were alarming, as some *Acropora* species could face functional extinction in the eastern Gulf of Thailand (Yeemin et al., 2013b). Additionally, the rapid growth of tourism, meaning an increased number of people visiting the reefs, led to additional physical damage, resulting in the temporary closure of dive sites, especially those in Marine National Parks (Yeemin, 2012).

The offshore reef at Losin Pinnacle appeared to be only minorly impacted by the mass coral bleaching that occurred in 2010, with relatively high live coral cover after the bleaching event. After the third global bleaching event in 2016, Sutthacheep et al. (2019) noted a decrease in bleaching relative to past bleaching events, with only 5% of the corals bleached. This mild bleaching could be due to its local conditions: surrounded by open sea, with strong currents and internal waves, which could dampen the impacts of increased temperature (Williams et al., 2010; Schmidt et al., 2016). The fishing activity around Losin Pinnacle may be an additional source of damage, as ghost fishing nets and gear have recently been found covering parts of the reef (Marine and Coastal Resources Research and Development Institute, 2018). The goal of this study was to supply the Ministry of Natural Resources and Environment with adequate information on the coral diversity and abundance found at Losin Pinnacle to establish baseline values for the reef in support of a marine protected area (MPA) proposal.

MATERIALS AND METHODS

Losin Pinnacle (Figure 1) is used as a base for lighthouse operations approximately 72 km from shore and is also known as one of the most southern popular dive sites in the Gulf of Thailand (844 SCUBA dives were recorded in 2017). This area is dominated by annual southwest and northeast monsoons during May–October and November–February, respectively. The wind speed toward the southwest direction is mostly higher than in other directions (Supplementary Table S1). An islet area is slightly above sea level, and the sea had a very small tidal range of about 50 cm (Supplementary Table S2). Surveys were conducted between 2015 and 2017 at six locations surrounding the reef. Belt transects, 30 m long × 2 m wide, with three replicates, were set parallel to the shore of the pinnacle in an anticlockwise direction at ST1–ST6 (Figure 1). Sites ST1, ST3, and ST5 were fixed at 20 m in depth for deep transects, whereas ST2, ST4, and ST6 were fixed at 10 m in depth for shallow transects. Underwater photographs ($n = 60$) were taken along each transect for assessment of benthic percentage cover. All images were analyzed by Coral Point Count with Excel extensions, using CPCE software (Kohler and Gill, 2006), and the benthic percentage was calculated. Coral species were recorded using a combination of belt transects and roving driver survey outside the belt transects in order to better assess true coral

species diversity. The roving searches were done in shallow and deep areas, near the belt transects, covering 10–15 m and 20–25 m in depth, respectively. Coral photographs were taken, and some coral samples were collected for microscopic investigation when the researchers could not identify them *in situ*. All species were identified by morphological characteristics according to <http://www.coralsoftheworld.org> and others (Veron and Pichon, 1976, 1980, 1982; Veron et al., 1977; Veron and Wallace, 1984; Hoeksema, 1989; Wallace, 1999; Veron, 2000; Wallace et al., 2012). Genetic identification was not used in this study due to cost limitations. In addition, environmental parameters were measured *in situ* at sites ST1, ST3, ST5, and ST7 during August 28–30, 2017. The seawater temperature, salinity, pH, and dissolved oxygen data were recorded at 5 m depth from the sea surface by YSI Pro Plus Multi-Parameter Water Quality Meter (YSI Incorporated, Xylem Inc.), and the visibility distance was measured by Secchi disk (Supplementary Table S3).

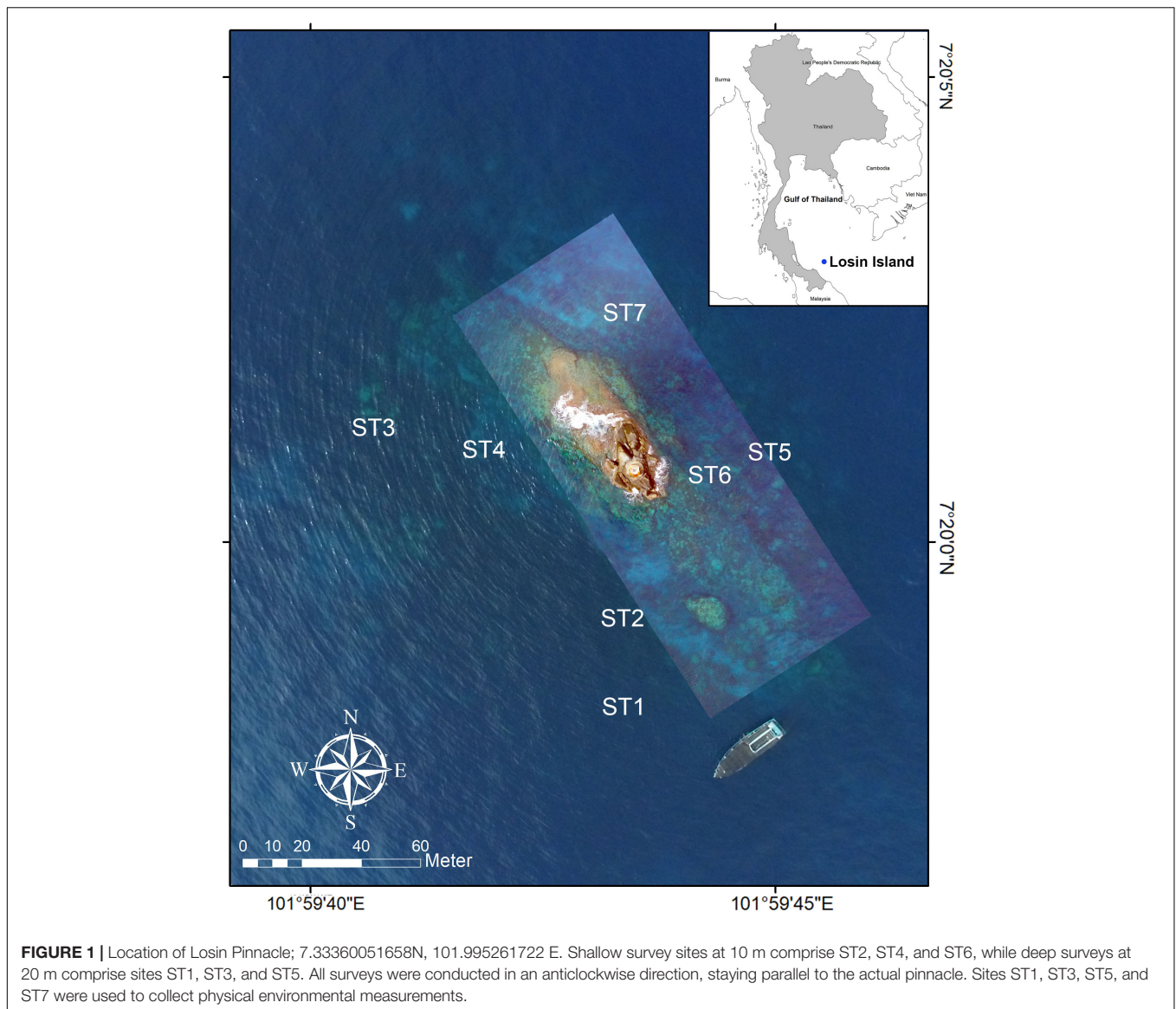
RESULTS

Losin Pinnacle consists of a reef area encompassing about 65,000 m² and is associated with good water quality. The reef compositions on the south and west sides were different from on the east due to different levels of exposure to waves. As shown in Figure 2, it is clear that sites ST1–ST4 had high live coral coverage; 97%, 85%, 77%, and 95%, respectively. Dense *Acropora* communities at those sites included *A. intermedia*, *A. grandis*, *A. hyacinthus*, and several corymbose species. Some *Montipora*, *Porites*, and *Pocillopora* were found interspersed. Live corals at sites ST5 and ST6 showed lower percentage coverage, at 45% and 52% live hard coral cover, respectively. This windward side was dominated by large colonies of *Porites*, *Pocillopora*, and some branching *Acropora*.

A total of 76 hard coral species (Supplementary Data Sheet 1) were found, with *Acropora* species representing the largest number of species. The most dominant *Acropora* species were the arborescent, i.e., *A. grandis*, *A. intermedia*, and *A. muricata*, and the tabulate forms, i.e., *A. cytherea*, and *A. solitaryensis*. The other common *Acropora* species were of various forms; tabulate (*A. hyacinthus*, *A. subulata*), arborescent (*A. florida*, *A. robusta*), corymbose (*A. divaricata*, *A. hoeksemai*, *A. latistella*), and corymbo-tabulate (*A. valenciennesi*).

DISCUSSION

Highly abundant and diverse *Acropora* populations are uncommon on most inshore reefs in the Gulf of Thailand, making the coral community at Losin Pinnacle a unique potential reservoir of *Acropora* diversity. After the 2010 bleaching event, coral communities in the Gulf of Thailand have been dominated by bleaching-resistant taxa, with a lower coral diversity than in previous periods (Sutthacheep et al., 2013, 2019). Losin Pinnacle has a much higher species diversity, over 75 species, compared to other Thai reefs; 47 species were recorded from twelve sites in the Andaman Sea (Phongsuwan



and Chansang, 2012), and only 44 species were recorded from six sites in the Gulf of Thailand (Yeemin et al., 2009; Sutthacheep et al., 2012, 2013). Though the overall area of the reef at Losin Pinnacle is relatively small, the coverage of live coral is high relative to other Thai reefs, which typically have live coral cover ranging from approximately 8% to 45% (Phongsuwan et al., 2013; Yeemin et al., 2013a; Sutthacheep et al., 2015). Additionally, Losin reef is rich in fish (111 species, personal communication), and other benthic organisms such as ascidians, octocorals, echinoderms, crustaceans, and sponges (Darumas et al., 2018; Marine and Coastal Resources Research and Development Institute, 2018).

This reef should be considered as a restricted area in which there would be appropriate conservation strategies; specifically, an MPA. The designated MPA would also aim to integrate social and ecological aspects, as previous successful MPAs have done, to increase its effectiveness (Ban et al., 2011). Although it would

not be protected against high seawater temperature, setting up an MPA with proper enforcement would reduce the vulnerability of corals to anthropogenic disturbances (Keller et al., 2009; Selig and Bruno, 2010; Wilson et al., 2012) through restricting use of the sea around Losin Pinnacle and limiting excessive use of the reef by tourists or fishermen.

Our baseline coral data, along with awareness and education sessions on coral bleaching, have encouraged the authority (Department of Marine and Coastal Resources) to draft an MPA plan for Losin Reef. After conducting the final public hearing with relevant agencies and stakeholders on October 2018, the proposal submitted to the National Policy and Plan Committee on Marine and Coastal Resources is currently under discussion, and in the future, hopefully, the MPA will be enacted. The next step will be preparation for the legal act, and it is expected to be put into force by the end of 2020. It is strongly suspected that the output from this study will actively support

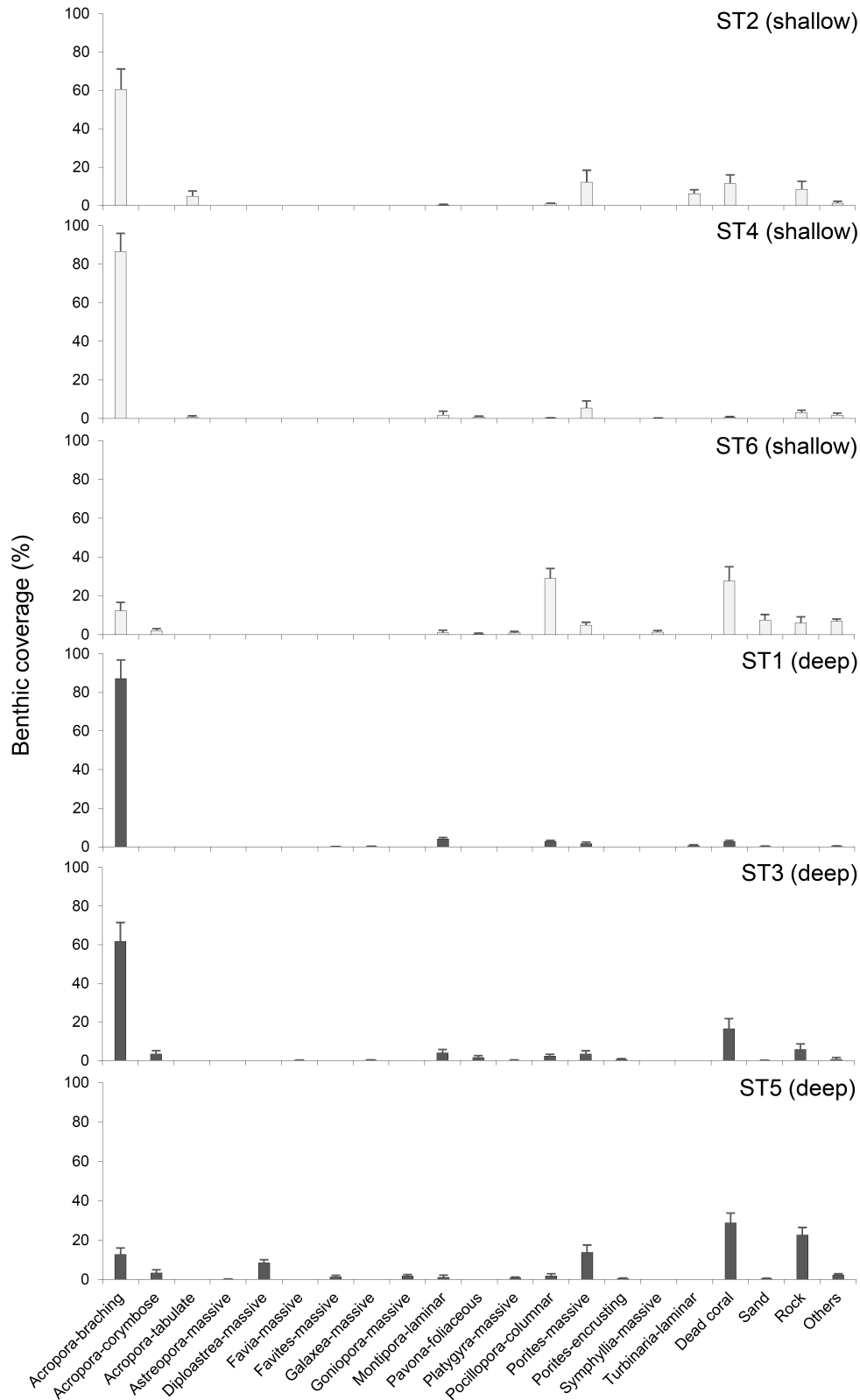


FIGURE 2 | Benthic cover data (mean + SD) observed from three shallow (10 m) and three deep (20 m) stations around Losin Pinnacle during August 2017. Percentage cover was calculated from photographs taken every half meter with three replicates at 30-m belt transects. Corals were divided into growth forms, and several abiotic variables were measured. Others represent benthic organisms other than hard corals.

Thailand's management plan under the Act on the Promotion of Marine and Coastal Resources Management B.E. 2558 (2015). The importance of Losin Pinnacle as a source of coral diversity for other reefs and as a potentially resilient reef to increased ocean temperatures should be further assessed in the future for population genetics and oceanographic studies.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation, to any qualified researcher.

AUTHOR CONTRIBUTIONS

MY, AC, SN, and UD conceived and planned the main idea. SN supervised the project for surveying the coral reef at Losin Pinnacle and planned the underwater coral studies. NP, MY, and AC contributed to sample collection and the identification of corals. MY, NP, and SN contributed to the data collection and analyzed coral reef status. MY and NP interpreted the results with support from AC. UD, ST, and SP wrote the project on "Draft of the Announcement of the Losin Pinnacle Marine Resources Protected Area" and contributed to public hearings with the support of MY. MY performed the data analysis and wrote the manuscript with support from NP and AC. MY, AC, NP, and SN provided **Supplementary Material**. All of the authors carried out the field studies and discussed the results related to the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2020.00130/full#supplementary-material>

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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