Long-term changes and restoration measures of soft corals (*Dendronephthya* spp.) at Mu Ko Similan National Park, the Andaman Sea

J. Putthayakool, P. Plangngan, T. Yeemin, W. Klinthong, M. Sutthacheep

Abstract Soft corals, *Dendronephthya* spp., are members of 19 genera (in four families) of soft corals found in Thai waters. In the Andaman Sea, *Dendronephthya* spp. is dominant at several coral reefs. Their beauty and color attract divers to these reefs making them popular diving destinations. In this study, we investigate the long-term changes of the soft corals, *Dendronephthya* spp., from 2009 – 2013 in three study sites of the Mu Ko Similan National Park, one of the most frequented diving destinations in the Andaman Sea. We found that the average percent covers of *Dendronephthya* spp. were significantly different among the study sites. The highest coverage of *Dendronephthya* spp. was observed at West of Eden while the lowest one was recorded at Ao Faiwab. Significant temporal variation was also detected among years. Reduction in soft coral bottom cover as influenced by certain environmental factors and rapid growth of tourism. The number of tourists visiting Mu Ko Similan in 2013 was nearly doubled compared to that in 2011. Based on our analysis, controlling tourism impacts on soft corals could be possible by implementing the following measures: 1) setting appropriate management action plan with the implementation of effective enforcement and regulation of diving activities; 2) establishing zoning and their appropriate carrying capacity for tourists in certain areas and 3) enhancing research and techniques on soft coral restoration.

Keywords: soft coral, *Dendronephthya*, diving, management, Andaman Sea

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Introduction

Soft corals are generally found in many coral reef habitats and are most abundant in tropical region (Benayahu et al. 1987; Dai 1990; Dahan and Benayahu 1997; Fabricius and Dommisse 2000) including Thai waters. It was reported that soft coral cover could reach 34.4 % of the total area of coral reefs after the coral bleaching event as reported at Sesoko Island, Japan (Loya et al. 2001). A previous study noted that at least 4 families comprising 19 genera were found in Thai waters: Alcyoniidae: Sinularia, Dampia, Cladiella, Klyxum, Sarcophyton, Lobophytum, and Eleutherobia; Nephtheidae: Nephthea, Stereonepthya, Scleronephthya, Dendronephthya, and Umbellulifera; Nidaliidae: Nidalia, Siphonogorgia, Chironephthya, and Nepthyigorgia; and Xeniidae: Xenia, Heteroxenia, and Sansibia (Chanmethakul et al. 2010). The soft corals *Dendronephthya* spp. are in the family Nepthedae which can be found in both the Gulf of Thailand and the Andaman Sea. However, this species is found as a dominant group in the Andaman Sea. Because of their colorfulness and beautifulness, they are fascinating to divers at several coral reefs in Thailand supporting these reefs to be as popular diving hotspots. Generally, soft corals are found on hard substrates such as rocks or hard corals, even in the habitats exposed to strong tidal currents (Benayahu et al. 2004). The higher occurrence of this soft coral is found in offshore than inshore reefs. Some soft corals can have a negative interaction with stony coral growth and survivor (Maida 1995). However, the understandings about the ecological aspects of soft corals in Thai waters are still insufficient, especially their abundance and distribution patterns. In this study, we examined the spatio-temporal distribution of the soft coral *Dendronephthya* spp. at three study sites around Mu Ko Similan one of the popular dive sites in the Andaman Sea.

Materials and methods

A belt-transect method was used to investigate distribution pattern of *Dendronephthya* spp. at three study sites in the Andaman Sea including (Figs. 1, 2); 1) Hin Muan Deaw (8°34'13.43" N, 97°38'51.00" E; 2) West of Eden (8°35'45.27" N, 97°38'6.13"E; and 3) Ao Faiwab (8°38'15.87" N, 97°39'12.36"E) during 2009 – 2013. At each study site, three permanent belt transects of 50 x 1 m^2 were placed at the depths 15-20 meters in which the percent covers of *Dendronephthya* spp. and available substrates were investigated. The square root transformation of the primary was performed prior to analysis of variance to meet the assumptions of normality and homogeneity of variance. A two-way ANOVA was performed

to examine the influence of time and study sites, on the percent cover of *Dendronephthya* spp. Multiple comparisons with Fisher's LSD was then analyzed to determine whether at least the two group averages were significantly different from each other.

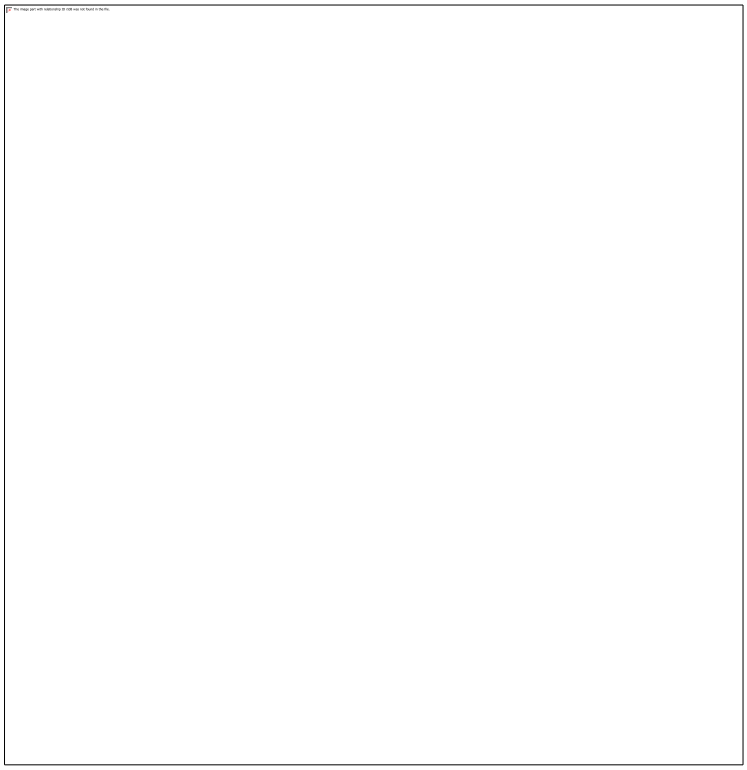

Fig. 1 Locations of the study sites in Mu Ko Similan, the Andaman Sea

Results and Discussion

The distribution of *Dendronephthya* spp. in Mu Ko Similan, the Andaman Sea was observed in a depth range of 15-20 meters showing different patterns among the study sites. The colonies of *Dendronephthya* spp. were commonly found on rocky substrate and dead corals. The highest coverage was recorded at West of Eden in 2011 with a coverage of 3.8% while the lowest one was found at Ao Faiwab.

The ANOVA results showed both temporal and spatial variation of the soft coral cover (Table 1). Spatial variation of the average percent cover of *Dendronephthya* spp. were significantly different among study sites (MS= 3.99, $F_{2,30}$= 1083.78, p<0.01).The average bottom cover of *Dendronephthya* spp. at West of Eden (2.62 ± 0.09% mean ± SE) was significantly different to that at Ao Faiwab (0.06 ± 0.005% mean ± SE) and Hin Muan Deaw (1.89 ± 0.104%, mean ± SE) (p<0.05). Similarly, significant differences in the average soft coral cover between Ao Faiwab and Hin Muan Deaw was also detected (p<0.05).

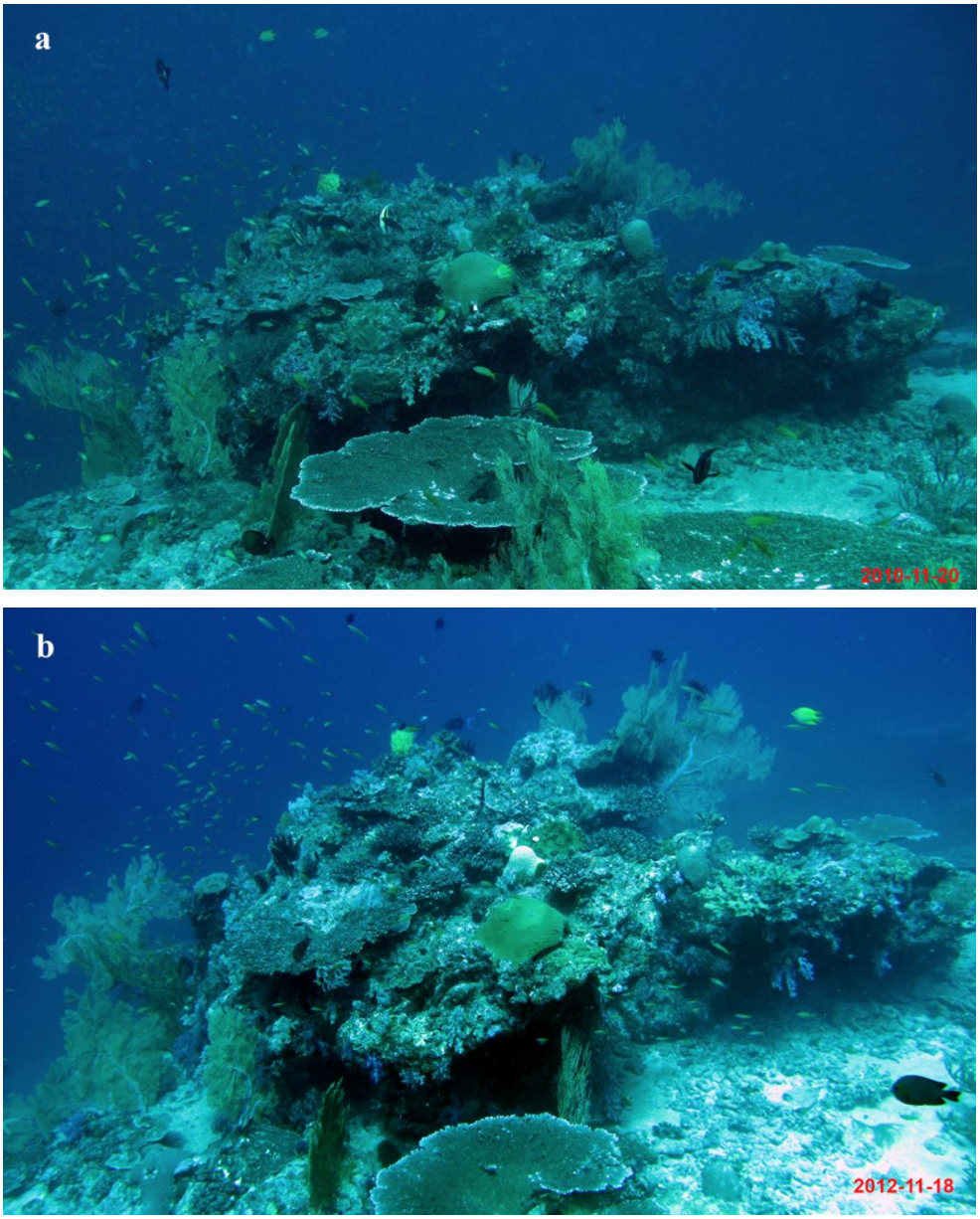

Fig. 2 Soft coral *Dendronephthya* spp. found at West of Eden in Mu Ko Similan, the Andaman Sea in A) 2010 and B) 2012

In terms of temporal variation, we observed significant changes of *Dendronephthya* spp. coverage in some years at each station (MS= 0.37, $F_{4,30}$= 101.46, p<0.01). At Hin Muan Deaw, the percent cover of *Dendronephthya* spp. in 2001 was the highest with significant differences with other years. Similarly, the percent cover in 2012 was also significant to that in other years (p<0.05). No statistical difference between year 2009, 2010, and 2013 was found (p>0.05).

At the West of Eden, the percent covers of *Dendronephthya* spp. in 2009, 2010, and 2011 were not significantly different ($p>0.05$) while a significant decrease was found after 2011 ($p<0.05$). The percent cover in 2013 was also different to that in the other years. At Ao Fai Wab, the percent cover of *Dendronephthya* spp. in 2011 was significantly increased compared to that in 2009 while the percent cover in 2009 and 2010 was not different ($p<0.05$). No coverage of *Dendronephthya* spp. was found in the belt-transects during 2012 – 2013 (Table 1, Fig. 3).

Table 1 Output of two-way ANOVA illustrating spatial and temporal variation of soft coral (*Dendronephthya* spp.) cover

Source of Variation	*df*	*Mean Square*	*F*	*p-value*
Study sites	2	3.99	1084.3	<0.001
Years	4	0.37	101.46	<0.001
Study sites x Years	8	0.20	54.71	<0.001
Residual	30	0.004		

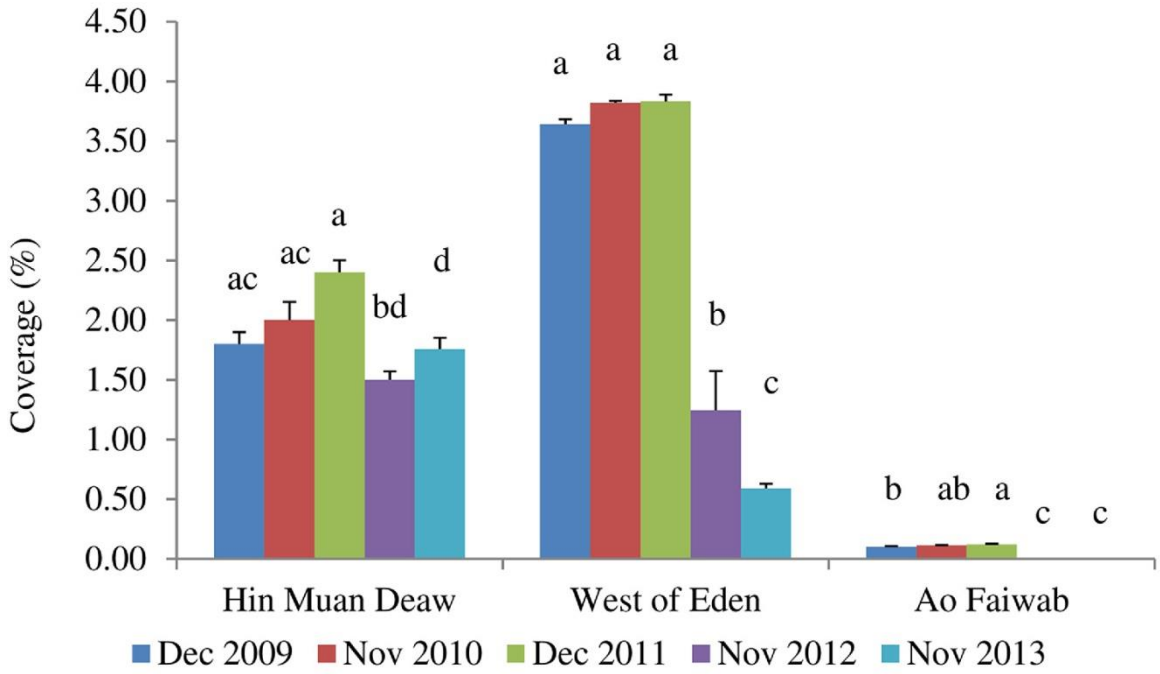

Fig. 3 The temporal variation of the percent bottom cover of soft coral (mean ± SE) for each study site in 2009, 2010, 2011, 2012, and 2013. Significant difference ($p<0.05$) as determined by multiple comparison test with Fisher's LSD

Available substrate is one of the important factors controlling the distribution patterns and abundance of *Dendronephthya* spp. while temporal variation could be influenced by various factors such as turbidity, temperature, depth, current, nutrients, etc. (Klintong and Yeemin 2012; Yeemin et al. 2012; Rozirwan et al. 2014). However, the decline of soft coral cover in 2012-2013 could be mostly caused by the influence of hypoxia with internal wave. Hypoxia refers to an area in which the low oxygen concentration of water is found (Hellya and Levin 2004). This event occurred in early 2007 affecting many reefs in the Andaman Sea. It was reported that brown plumes were seen in the water where dead fish, invertebrates and soft corals were observed. The internal waves that related to a range of climatic-oceanographic factors, could generate upwelling of cold deeper water with very low oxygen which affected soft corals and other animals (Phongsuwan et al. 2013)

The illustration above describes the environmental factors influencing the distribution of soft corals. However, anthropogenic impacts are also noted, especially sewage from tourist boats (Yeemin et al. 2006; Samsuvan and Yeemin 2012; Suraswadi and Yeemin 2013). Practically, the reduction of anthropogenic impacts is more possible than controlling impacts of natural disturbances. Based on our analysis, controlling tourism impacts on soft corals in Mu Ko Similan National Park, the Andaman Sea could be feasibly implemented as the following measures:

a) *Setting appropriate management action plan as well as effective enforcement of regulations*

Although Thailand' marine national park are protected under the National Park Act, B.E. 2504, the Act needs to be updated to conform to the present and future situations. Hence, the reform of relevant regulations, establishment of appropriate management strategies and action plans are urgently required to control tourism impacts and to promote sustainable tourism in Mu Ko Similan National Park. Effective enforcement of regulation should be also implemented to support effectiveness of those regulations.

b) *Establishing zoning and the appropriate number of tourists in certain areas*

Zoning is a very important tool for effective resource utilization in marine national park. Integration of scientific knowledge, appropriate utilization, and stakeholder participation as well as legal instruments should be involved in zoning and decision-making process. Appropriate number of tourists should be established in order to ensure that tourism impacts are not over the carrying capacity of certain areas (Emphandhu et al. 2006).

c) *Enhancing research and on soft coral restoration techniques*

Scientific knowledge on soft coral restoration is still very limited in Thailand, research and studies on soft coral restoration techniques should be urgently supported in order to improve the understanding of soft corals and restoration techniques to mitigate for the negative impacts enhance natural recovery and the resilience of soft corals in the face of both anthropogenic and natural disturbances.

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