Songklanakarin J. Sci. Technol.
40 (6), 1437-1445, Nov. - Dec. 2018

http://www.sjst.psu.ac.th

Original Article

Number of tourists has less impact on coral reef health than the presence of tourism infrastructure

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Received: 17 July 2017; Revised: 22 August 2017; Accepted: 7 September 2017

Abstract

Tourism has long been the focus of tourism marketing for countries, such as Thailand, largely because of perceived economic benefits. However, tourism is implicated to be one of the major causes of coral reef degradation. Reef tourism may impact reefs through direct activities such as diving and snorkelling, as well as indirect impacts from poorly planned coastal development and overharvesting of marine life to support tourism-associated businesses. Separating direct and indirect impacts is problematic where infrastructure exists; however, these impacts were investigated separately in the same area. In this study, we compared the prevalence of coral diseases and prevalence of signs of compromised health to distinguish direct and indirect impacts between coral reefs that have different levels of visitation and infrastructure. Surveys of reefs throughout eastern Thailand indicated poorer health of reefs near infrastructure rather than reefs at more isolated islands. Visitation intensity influenced reef health only where no infrastructure was present. We also found significant increases in nitrate, ammonium, phosphate, and total suspended sediment toward sites near infrastructure, whereas different levels of visitation made no difference to these metrics. Managers necessarily must devise a compromise between the convenience of siting tourism infrastructure close to the desired location and the ecological consequences of doing so.

Keywords: impact of tourism, coral disease, tourist intensity, tourism infrastructure

1. Introduction

Coral reefs are amongst the most vulnerable marine ecosystems from local and global impacts. Nevertheless, coastal tourism has become an important source of economic development in many countries, often generating much-needed foreign income (Norris-Spalding *et al.*, 2017). It has long been a focus of tourism marketing for countries such as Thailand, largely because of the perceived distribution of benefits to otherwise low-output areas (Wattanakuljarus & Coxhead, 2008). Approximately 30 million international visitors arrived in Thailand during 2015 (Department of Tourism, 2015), many of whom remained at or near the coast for the duration of their stay. Of the USD 45 billion reported as direct tourism income for Thailand in 2015, more than half (around 8% of total GDP) came from coastal provinces. Coral reef tourism in most of Asia is seldom environmentally neutral and has been associated with ecosystem degradation and loss of biodiversity through direct activities such as diving and snorkelling, as well as indirect impacts arising from poorly planned coastal development and overharvesting of marine life to support tourism-associated businesses (Norris-Spalding *et al.*, 2017). Marine tourism activity and the real estate and infrastructure development generated by the tourism industry can exact a significant toll on coastal ecosystems that impact mainly the mangroves and the coral reefs which are at the very heart of the ecosystem wealth and attractiveness of the coastline.

Even where ecosystem-based management approaches are applied for coral reefs, they have focused

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overwhelmingly on reducing fishing pressure with little attention being paid to other ecologically threatening human activities (Birkeland, 2017; Gil, Renfro, Figueroa-Zavala, Penie, & Dunton, 2015; Norris-Pandolfi *et al.,* 2005). Where fishing is not the primary focus, artificial and portmanteau metrics, such as carrying capacity of reefs, have been attempted (Zhang, Chung, & Qiu, 2016), based on the concept that the number of tourists visiting a site is *ipso facto* related to the severity of the perceived impact. The problem with such metrics, and the thinking behind them, is that the links between tourism and coral reef health are understandable in relatively simple terms. Flaws in such simplistic methodologies are evident when the complexities of reef ecosystems are incorporated into surveys of reef condition (Díaz-pérez, Rodríguez-zaragoza, Ortiz, & García-rivas, 2016) and when the differences between localities and tourism intensity overwhelm the signal of the impact (Nepote, Bianchi, Chiantore, Morri, & Montefalcone, 2016; Norris-Ferrigno *et al.,* 2016). Regardless of how one measures impacts or stress, the perceived economic benefits of reef-based tourism make it attractive for resource managers as a source of income and employment for stakeholders. Almost universally, managers are aware that excessive tourism is likely to be detrimental to the coral reef resource upon which it is predicated, but feel that limiting the amount or nature of the tourism will provide an acceptable balance between impact and income, often referred to as "sustainable tourism" (Norris-Lucrezi *et al.,* 2017). The concept of sustainability, however, requires that managers have a willingness to sacrifice services and activities in order to reduce the harm caused to biodiversity (De-Miguel-Molina, De-Miguel-Molina, & Rumiche-Sosa, 2014) since often the value of the resource is tied to the perception that the activities are sustainable (van Beukering, Sarkis, van der Putten, & Papyrakis, 2015). But what should they sacrifice? Should they forgo the income of large numbers of guests or the convenience of siting resorts and pontoons at the most desirable locations or should they limit the types of activities they provide on-site?

Studies on the Great Barrier Reef showed that even quite low-key infrastructure can negatively impact coral reef health (Lamb & Willis, 2011), especially in places where overall visitation is low. Likewise, the number of visitors at a site can reflect a level of physical damage (Zhang *et al.,* 2016) or degradation (Lamb, True, Piromvaragorn, & Willis, 2014). While these factors have been investigated separately, it is difficult to find areas where the combined or separate effects of tourism support infrastructure and visitation intensity may be discriminated. Here, we examine the effects of both visitor numbers and nearby tourism infrastructure along the east coast of Thailand in a region which has invested heavily in intensive coastal tourism.

2. Materials and Methods

2.1 Site selection

We conducted systematic surveys in 24 selected coral reefs along the eastern coast of Thailand (A description of the study sites are provided separately in a supplementary document). The surveyed sites were assigned into two groups by proximity to coastal tourism infrastructure which was defined especially as a hotel or resort development at a beachside or a tourist pier: 1) "Near Infrastructure" (NI) and 2) "Isolated from Infrastructure" (IS). Each group was comprised of 12 sites. In each infrastructure category, the sites that were identified by local tour operators as receiving relatively few (<50) tourists each day were categorized as "low visitation sites" (LV: 6 sites) and those exposed to higher levels of tourism (>50) tourists each day were placed in the "high visitation sites" (HV: 6 sites) category.

We recorded the number of visitors at each site over the 3-h peak visitation period to verify visitation intensity. We assumed since the groups overlap in space and are otherwise indistinguishable in terms of ecology, that both infrastructure categories received equal impact from the broad scale stresssors and impacts such as mass bleaching.

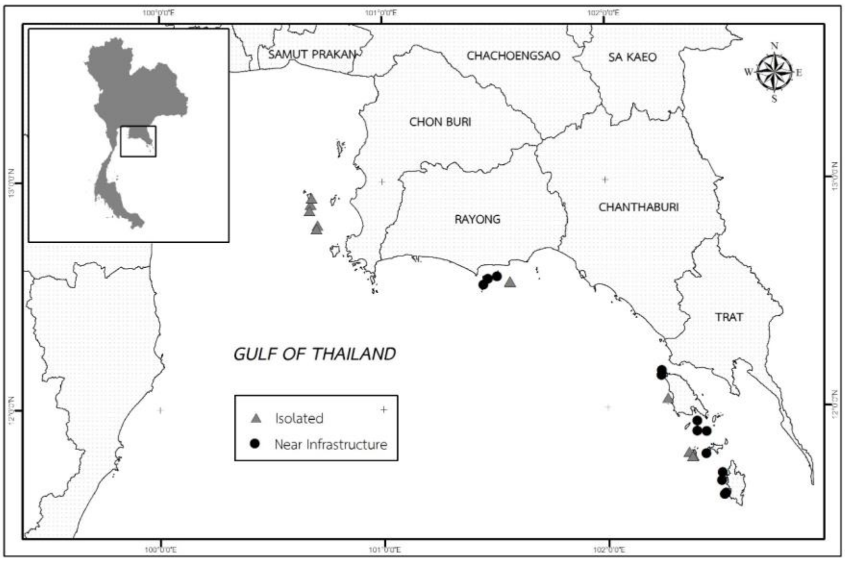

Figure 1. A total 24 coral reefs were surveyed throughout the eastern coast of Thailand. Study sites were assigned into 2 groups: near infrastructure group (bold circle), and isolated from infrastructure group (triangle).

2.2 Data collection

Field surveys were undertaken over a one-month period in late 2013. We collected data following the standard method of belt transect survey, described in Hill and Wilkinson (2004), with four randomly-laid 25x1 m belt transects just below the reef crest, parallel to the shore at 4-6 m depth, at each site. For each transect, data was collected on generic composition and abundance of the coral community, incidence of disease, other signs of ill-health, and any environmental data that might be relevant. Disease identification was undertaken in accordance with the standard protocol described by (Raymundo, Couch, Bruckner, & Harvell, 2008). All coral colonies that were encountered within the belt transect were counted to obtain total colony counts. For each coral colony, we noted occurrence of coral disease, i.e. white syndrome and growth anomaly, and other signs of compromised health, i.e. focal and non-focal bleaching, algal or sponge overgrowth, partial mortality and pigmentation response. For the most part, it was not possible to attribute direct causes to observed lesions, although bites from parrotfish (Scaridae) and puffer fish (Tetraodontidae) were distinctive. Colonies with ambiguous or unusual signs and symptoms were photographed for later study.

At each site, we collected a water sample from 1 m below the water surface using Nansen bottles which were then stored on ice. The water samples were later analyzed at Burapha University in Chantaburi to obtain quantitative measures of nutrient concentration, including nitrate, nitrite, phosphate, ammonia, as well as estimates of total suspended sediment and total coliform bacteria. Water parameters were analyzed following a standard protocol described by Pollution Control Department (2004).

2.3 Data analysis

"Community prevalence" of coral disease incidence and signs of compromised health at each site was calculated by dividing the number of observed cases from all transects by the total number of coral colonies (Raymundo *et al.,* 2008). The association of overall diseases and signs of compromised health in all locations were investigated using the principle component analysis (PCA) based on square root transformed data for all sites.

Since the disease prevalence and prevalence of signs of compromised health included many zero values and failed to meet the assumption of variance homogeneity and thus ill-suited to standard ANOVA, we used a non-parametric Kruskal-Wallis test (Ruxton & Beauchamp, 2008; Zar, 1999) to investigate differences in the mean values of coral diseases and health indicator prevalence and signs of compromised health prevalence between the infrastructure and visitation groups.

We investigated the differences in concentration of water parameters between the groups using the Analysis of Similarity (ANOSIM) based on square root transformed data. The distribution of sites was illustrated using non-metric Multidimensional Scaling based on Bray-Curtis similarity. Data were ordinated using logarithm-transformed data. Different concentrations of water parameters between sites with differing levels of visitation within groups were obtained and compared using the Kruskal-Wallis test. We tested the correlation between water parameters and the prevalence of coral disease and signs of compromised health using Spearman's rho test (Zar, 1999).

3. Results

3.1 Association of infrastructure to coral diseases and sign of compromised health

Two common diseases, namely coral growth anomaly (GA) and white syndrome (WS) and six signs of compromised health, namely bleaching (BL), predation scarring (PRED), sponge overgrowth (SP), algae overgrowth (AL), partial mortality (PM) and pigmentation response (PR) were encountered during this study.

The PCA result showed that the mean prevalence of coral diseases and signs of compromised health were associated more with sites nearby tourism infrastructure than with sites in the isolated group (Figure 2, first 3 component axes accounted for approximately 66.7% of variation). PCo1 appears to be driven mostly by prevalence of GA, PRED, and AL, whereas PCo2 was driven mostly by prevalence of BL, PRED, and PR. The third component PCo3 was driven by prevalence of WS and PM (Table 1 and Figures 2A, 2B). The 3-D PCA diagram illustrated a separation between the NI and IS groups. The NI group was characterized by a combination of high prevalence of algae overgrowth, partial mortality, growth anomaly, white syndrome and predation scar, whereas the isolated group was associated with a high prevalence of PR and SP (Figure 2B).

We found that, although bites from parrotfish (Scaridae) and puffer fish (Tetraodontidae) were distinctive, areas of tissue loss due to other predation, for example Drupella, were indistinguishable from other sources of partial mortality, such as mechanical abrasion by divers' fins, at these sites. The category PM may thus include sources of mortality from several factors.

This separation of disease prevalence at the sites close to and further from the infrastructure is illustrated by direct comparison of the incidence rates of each indicator. Coral reefs located close to tourism infrastructure were susceptible to algae overgrowth, partial mortality, growth anomaly and possible pathogens related to white syndrome (Figure 3, Table 2). The mean (SE) prevalence of algae overgrowth at the NI group (12.60±1.55%) was 8-fold higher than isolated group (1.59±0.43%). The mean (SE) prevalence of partial mortality at the NI group (8.02±0.94%) was twice as high as the isolated group (4.61±0.98%). Likewise, the mean (SE) prevalence of growth anomaly in the NI group (4.43 ±0.68%) was 4-fold higher than the isolated group (1.04±0.26 %). Although the mean (SE) prevalence of white syndrome at the NI group (2.16±0.78%) was 4-fold higher than the isolated group (0.50±0.21%), the very patchy distribution of the disease across sites meant that the difference was not statistically significant between categories. At some sites, the prevalence of WS was very high while at others it was largely absent. There appears to be no direct correlation between the prevalence of WS and coastal infrastructure, although there was a clear tendency for this syndrome to be present at higher than normal rates at these sites.

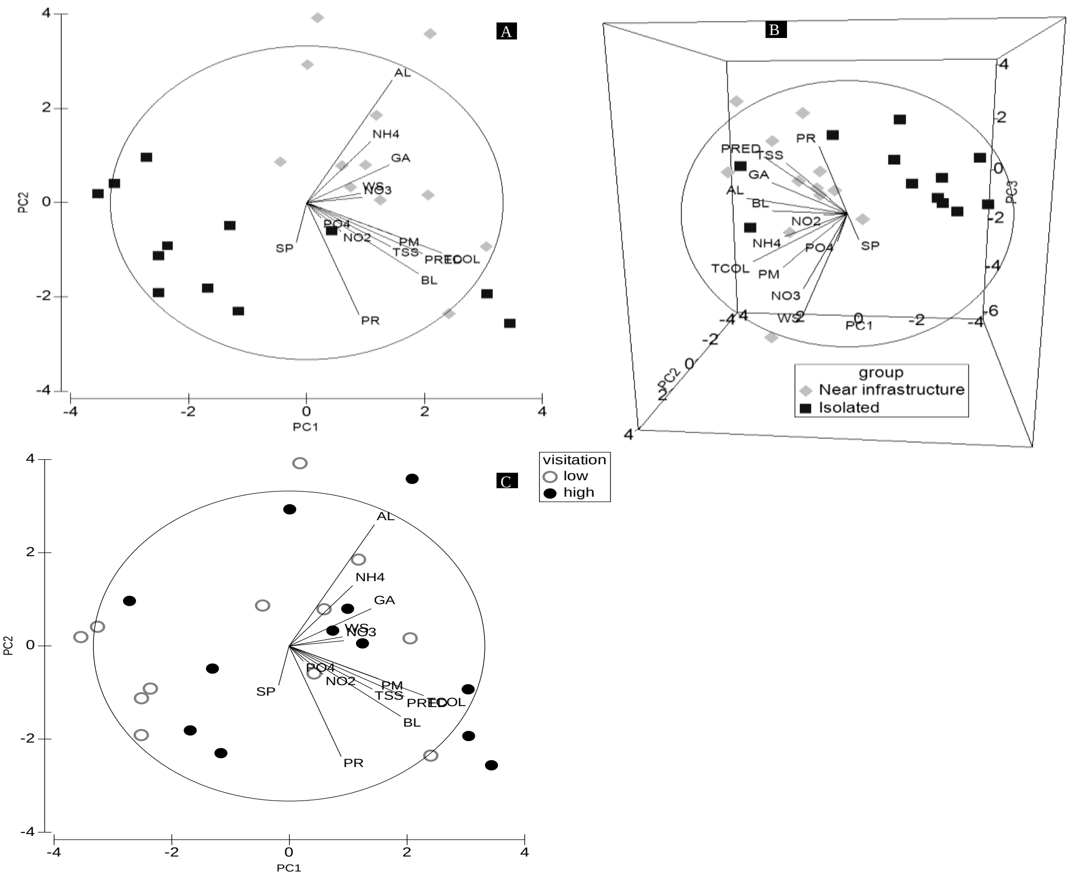

Figure 2. Principle component analysis of prevalence of coral diseases, signs of compromised health and water parameters in different groups (2A and 2B); near infrastructure group (light diamond) and isolated group (solid rectangular) and in different visitation (2C); low visitation (open circle) and high visitation (solid circle). PCo1, PCo2 and PCo3 account for 29.4%, 21.1% and 16.2% of total variance respectively. WS = white syndrome, GA = growth anomaly. Signs of compromised health: PR = pigmentation response, PM = partial mortality, BL = uncommon bleaching, AL= algae overgrowth, SP = sponge overgrowth, PRED = predation scar. Water parameters; NO_3 = nitrate, NO_2 = nitrite, PO_4 = phosphate, NH_4 = ammonia, TSS = total suspended sediment, TCOL = total coliform bacteria.

Table1. Eigenvalues, cumulative percent variation (Cum. %), and eigenvectors of a PCA examining the prevalence of diseases and signs of compromised health.

Variable	PC1	PC2	PC3	PC4	PC5
Eigenvector					
GA	0.325*	0.006	0.007	0.329	0.669
WS	0.070	-0.168	0.479*	-0.496	0.477
BL	0.113	0.297*	0.135	-0.306	0.014
PRED	0.397*	0.608*	-0.169	-0.442	-0.177
SP	-0.196	0.010	-0.060	-0.338	0.323
AL	0.808*	-0.305	-0.153	0.074	-0.068
PM	0.148	0.174	0.831*	0.268	-0.279
PR	-0.069	0.625*	-0.074	0.406	0.327
Eigenvalues	4.55	3.27	2.5	1.77	0.986
%Variation	29.4	21.1	16.2	11.4	6.4
Cum.%Variation	29.4	50.5	66.7	78.1	84.4
GA	0.325*	0.006	0.007	0.329	0.669
WS	0.070	-0.168	0.479*	-0.496	0.477

* indicate Pearson's correlation of axes to prevalence data; r>0.5

PCA = principle component analysis; GA = growth anomaly; WS = white syndrome; BL = uncommon bleaching; PRED = predation scarring; SP = sponge overgrowth; AL = algae overgrowth; PM = partial mortality; PR = pigmentation response.

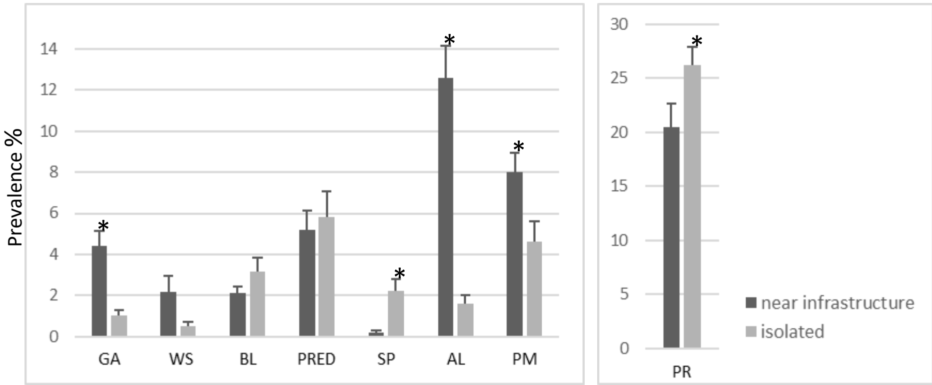

Figure 3. Mean prevalences of coral diseases and compromised health signs of near infrastructure group and isolated group. (* indicates significant level α=0.05).

Table 2. Mean prevalence of coral diseases and signs of compromised health compare between groups and between low and high visitation within each group.

variables	Between Groups			Between low and high visitation sites					
				Near infrastructure group			Isolated group		
	Chi-Square	df	Sig.	Chi-Square	df	Sig.	Chi-Square	df	Sig.
GA	16.86262	1	0.000*	0.922492	1	0.34	2.4599	1	0.12
WS	1.962305	1	0.161	0.516328	1	0.47	0.072197	1	0.79
BL	0.065528	1	0.798	0.888108	1	0.35	1.27899	1	0.26
PRED	1.124343	1	0.289	0.501486	1	0.48	9.522038	1	0.00*
SP	10.85494	1	0.001*	0.004036	1	0.95	2.561744	1	0.11
AL	46.32672	1	0.000*	0.287524	1	0.59	1.680032	1	0.19
PM	9.45485	1	0.002*	0.154501	1	0.69	1.808271	1	0.18
PR	7.959086	1	0.005*	3.877868	1	0.05*	0.224964	1	0.64
Nitrate	13.23691	1	0.000*	0.986014	1	0.32	5.387135	1	0.02*
Nitrite	0.495868	1	0.481	2.738928	1	0.10	21.54854	1	0.00*
Ammonia	55.54063	1	0.000*	0.109557	1	0.74	0.438228	1	0.51
Phosphate	1.11716	1	0.291	0.687135	1	0.41	0.986014	1	0.32
TSS	11.58906	1	0.001*	1.752914	1	0.19	1.351526	1	0.25
TCOL	20.42292	1	0.000*	6.131737	1	0.01*	10.2753	1	0.00*

* indicates significant level at α = 0.05
GA = growth anomaly; WS = white syndrome; BL = uncommon bleaching; PRED = predation scarring; SP = sponge overgrowth; AL = algae overgrowth; PM = partial mortality; PR = pigmentation response; TSS = total suspended sediment; TCOL = total coliform bacteria.

The mean (SE) prevalence of pigmentation response within the isolated group (26.21±1.71%) was higher than the NI group (20.08±2.14%). Likewise, the mean (SE) prevalence of sponge overgrowth within the isolated group (2.24±0.59%) was higher than the NI group (0.21±0.07 %).

3.2 Prevalence of coral diseases and sign of compromised health attributable to levels of visitation.

The level of tourism activity as the PCA ordination focus showed no particular distribution pattern that could be explained by the level of visitation across the infrastructure categories, whereas low visitation and high visitation sites within the isolated group had different distributions along PCo1, PCo2, and PCo3 (Figure 2C). It is likely that the ill-health signal attributable to the presence of nearby infra-structure masks any influence of visitor numbers.

3.2.1 Near infrastructure group

Within the NI group, the mean prevalence of coral diseases and compromised health signs between low visitation sites and high visitation sites was not significantly different with the exception of pigmentation response (Table 2). The mean (SE) prevalence of pigmentation response at high visitation sites (23.97±2.93) was significantly higher than the low visitation sites (6.99±2.99).

3.2.2 Isolated from Infrastructure group

Reefs in the isolated group subject to high visitation levels were susceptible to disturbance to a greater degree than low visitation reefs. There were significant differences in pre-valence of coral disease and signs of compromised health within the isolated group. High visitation sites in the isolated group were associated with a high prevalence of BL, PRED, PR, and a low prevalence of SP. In contrast, low visitation sites were associated with a low prevalence of GA, BL, PRED, and PR and a high prevalence of SP (Figure 4B, Table 2). The mean (SE) prevalence of growth anomaly at high visitation sites was approximately 4-fold higher than the low visitation sites (7.08±1.54% vs. 1.43±0.39%). The mean (SE) prevalence of predation scars at high visitation sites was approximately 4-fold higher than the low visitation sites (9.74±1.03% vs. 1.89±0.51%). There was also a non-significant trend for the mean prevalence of white syndrome, bleaching, algae overgrowth partial mortality, and pigmentation response at high visitation sites to be higher than the low visitation sites (Figure 4).

3.3 Concentration of water parameters

Coral reefs nearby infrastructure exhibited a high degree of similarity in terms of water parameters and differed from those in the isolated group (Figure 5). In general, water quality indicators were worse for the NI reefs than for the reefs further away. The mean concentrations of nitrate, ammonia, total suspended sediment, and total coliform of NI group were significantly higher than the isolated group, although nitrite and phosphate were not significantly different between the groups (Table 2).

The coral reefs of the isolated group which experienced high visitation rates had mean concentrations of nitrate, nitrite, and total coliform significantly higher than the sites with low visitation. The mean (SE) concentration of total coliform at the high visitation sites was 5-fold higher than that of low visitation sites (14.8±3.01 μg/L vs. 2.70±0.24 μg/L) ($P<0.001$). The water quality parameters of NI reefs were not significantly different between the high and low usage sites, suggesting that the source of the pollutants was land-based.

Increasing nutrient enrichment potentially increases the prevalence of coral diseases and is often associated with an increase in algae cover. The prevalence of white syndrome was significantly correlated to the nitrate concentration ($r=0.55$, $P<0.001$). The prevalence of pigmentation response was significantly correlated to total suspended sediment ($r=0.40$, $P<0.001$). The prevalence of algae overgrowth was significantly correlated to ammonia ($r=0.41$, $P<0.001$).

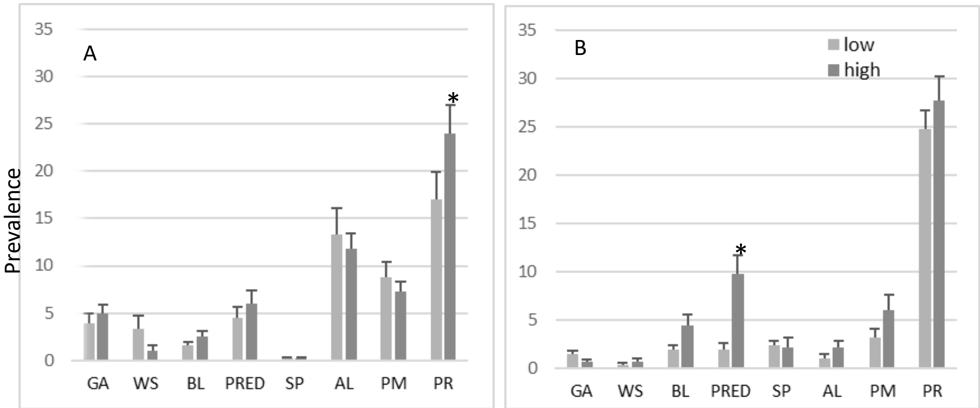

Figure 4. Mean prevalences of coral diseases: GA, WS, and signs of compromised health, BL, PRED, SP, AL, PM, PR, between low and high visitation sites within near infrastructure group (A) and isolated group (B).
* indicates significant level at α = 0.05.

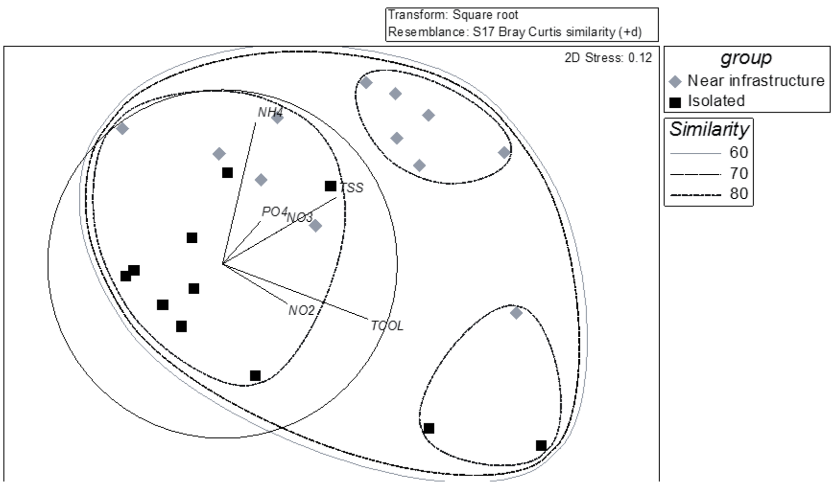

Figure 5. nMDS plot illustrates separated distribution of sites in near infrastructure group and isolated group based Bray-Curtis similarity of water parameters. The separation supported by one-way ANOSIM (global $R=0.36$, $P=0.002$).

4. Discussion

Sustainable tourism respects the fragile environmental balance that characterizes many tourism destinations, particularly in environmentally sensitive areas (UNESCO Office in Venice Sustainable Tourism Development in UNESCO Designated Sites in South-Eastern Europe Ecological Tourism in Europe -ETE, 2017). It relies heavily on the heath of the reef environment and socio-economic environments of the destinations. Tourism development can be of great benefit to the economy of coastal provinces, but it can also have negative impacts on the biophysical environment if not well planned, developed, and managed (Harriott, 2002). In this study, we found that the mere presence of tourism-related infrastructure adjacent to a coral reef can have negative effects on the health and viability of the reef environment. Studies on the Great Barrier Reef have shown that even quite low-key infrastructure can negatively impact coral reef health, (Lamb & Willis, 2011), especially in places where overall visitation is low. However, our surveys indicated that in eastern Thailand, these negative effects occurred regardless of the intensity of visitation (Figure 2C).

In the absence of tourism infrastructure, it is clear that visitor numbers (and types of activities) have some effects on the health of coral reefs. This relationship was previously noted in Thailand (Lamb *et al.*, 2014; Worachananant, Carter, Hockings, & Reopanichkul, 2008). However, the effects of high visitor numbers are different than the consequences of placing tourism-related infrastructure adjacent to reef areas. The PCA results showed that the mean prevalence of coral diseases and signs of compromised health were associated more with sites that were nearby tourism infrastructure than with sites in the isolated group (Figures 2A, 2B). Coral reefs located close to tourism infrastructure were susceptible to algae overgrowth, partial mortality, and to white syndrome-related pathogens to a far greater degree than those reefs isolated from infrastructure. The mean prevalence of algae overgrowth at the NI group was 8-fold higher than that of the isolated group. Furthermore, partial mortality from all sources was twice as high and the incidence of white syndrome averaged 4-fold higher although it was not ubiquitous. All of these symptoms of reef ill-health have been associated with poor water quality (Lamb, Water, Bourne, & Altier, 2017; Norris-Redding *et al.,* 2013), and in areas of high water quality, tourism infrastructure has been shown to be the smoking gun of disease outbreaks (Lamb & Willis, 2011). The coast of eastern Thailand has seldom claimed to have pristine water quality. Several large metropolitan areas adjacent to river mouths pump out large amounts of sediment and pollution from activities occurring further inland. Yet even in this region of apparently low signal to noise for the effects of lowered water quality, the results reported here are unambiguous. Resorts and hotels nearby reefs will have detrimental effects on the coral community.

Although regulations stipulating pollution mitigation measures to be undertaken when constructing and operating tourist facilities have been in existence for many years as stated in the Enhancement and Conservation of the National Environmental Quality Act (B.E.2553, 1992) and the Building Control Act (B.E.2522, 1979) which apply mainly to large operations. For the most part, however, pollution regulations have been developed to protect public health and to minimise physical degradation of the environment. There has – so far – been no evidence to indicate that nutrient loading and export of pathogens to the reef community will occur even in areas where the regulations appear to have been applied rigorously. Moreover, it is not clear to what extent these regulations are applied across jurisdictions, especially in regards to areas within the national parks, which operate somewhat independently of municipal and provincial regulations and have their own development and management criteria. Unfortunately, our results showed that nutrient loading and pathogen export have occurred in all locations where tourist facilities have been constructed which suggests that the regulations (or their implementation) may need to be renovated to enhance the sustainability of the industry.

Low visitation sites were associated with a lower prevalence of GA, BL, PRED, and PR and a higher prevalence of SP (Figure 4B, Table 2) than sites with high visitor numbers. Growth anomalies, bleaching, and pigmentation response have all been linked with tourism in other parts of the world, and are probably responses to micro-pollutants such as sunscreens, boat paints, and human waste materials. In areas with normally high water quality, such links have been used to restrict the number of visitors to a given site, establishing a reef community carrying capacity for humans. Here, we have seen that – in the absence of point sources of pollution associated with tourism infrastructure – visitor numbers were also correlated to increases in known tourism-related syndromes. Against a background of relatively poor water quality in eastern Thailand, the impact of excessive numbers of tourists is still evident. The increase in predation scars at highly visited sites seems at first incongruous, until one recalls the now-illegal, but still common practice of fish feeding at snorkelling sites. This has long been discouraged by Thai authorities, because of its many detrimental effects (Di Iulio Ilarri, De Souza, De Medeiros, Grempel, & De Lucena Rosa, 2008; Milazzo, Anastasi, & Willis, 2006) yet is strongly desired by tourists, who often disregard advice to refrain from the practice. Changes in the behaviour and composition of reef fish communities due to feeding activities in highly visited sites in eastern Thailand are likely to reflect the same consequences reported elsewhere in the world.

Reef-based tourism has been regarded as a marginal activity for fragile ecosystems for some years (Barker & Roberts, 2004; Gil *et al.,* 2015; Hall, 2001; Worachananant *et al.,* 2008). Especially for small island locations, intensity of tourism development has been linked to often dramatic declines in the quality of the very reef resource that the tourists seek (van Beukering *et al.,* 2015). In eastern Thailand, the tourism value of the resource is less tied to the perception that activities there are sustainable, but it is not entirely unrelated. While the value of reef-based activities (snorkelling, diving, site-seeing) relies largely on the perception that the activity is sustainable and that the environment is kept in relatively good condition, the value of tourism infrastructure does so to a much lesser degree. So long as tourists perceive that the facility and its immediate environment are clean, operators of shore-based tourist facilities are largely independent of the consequences of reef degradation (Siriwong & True, in prep). This places the managers of marine resources in somewhat of a predicament. Tourism development is seen mostly as a key to economic development that is reflected by the increased construction of shore-based facilities. The consequences of this development, however, are reflected in both socio-ecological terms (Green, 2005; Wongthong & Harvey, 2014) and in ecological terms (this paper). Managers necessarily must devise a compromise between the convenience of siting tourism infrastructure close to the desired location and the ecological consequences of doing so.

Acknowledgement

This study was fund by Research and Development Office and Graduated School, Faculty of Science, Prince of Songkla University. (Funding code: SCI550748S).

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