Tourism Threats to Coral Reef Resilience at Koh Sak, Pattaya Bay

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Abstract

Coral reefs provide many ecosystem goods and services and rising atmospheric greenhouse gas concentrations are resulting in higher than normal sea surface temperatures (SSTs), increasing the frequency and extent of mass coral bleaching and mortality. The loss of corals after bleaching events is often followed by changes in the reef community and the proliferation of macroalgae, especially in reefs experiencing tourism and fishing. This change, however, is less likely in reefs experiencing fewer negative impacts. Using a mixed methods approach to data collection we used boat-traffic surveys, coral reef substrate surveys and self-complete questionnaires and interviews of scuba divers, island visitors and their tour guides to assess potential tourism impacts to the coral reef at Koh Sak, Pattaya. The number of tourists, the intensity of boat traffic and poor management of activities at the island impair the structural and ecological integrity of the reef thereby affecting its ecological and spatial resilience and capacity to survive global climate change. To improve reef resilience, there needs to be a shift from exploitative business practices to a conservation-based industry that creates the infrastructure to ensure visitors participate in activities that help conserve the reef rather than weaken it.

Keywords: Global Climate Change / Coral Bleaching / Resilience / Tourism

1. Introduction

Coral reefs are unique ecosystems that are characterised by their biological community and calcium carbonate structure. Reefs provide many ecosystem goods and services (see Moberg and Folke, 1999 and references therein) and in a recent meta-analysis, the global economic value of coral reef goods and services (in 2007 US$) was estimated at 352 249 $ ha^{-1} yr^{-1} (de Groot et al., 2012), much higher than temperate and tropical forests, woodlands and grasslands combined (12 736 $ ha^{-1} yr^{-1}) and higher than previous estimates made in 1997 (Costanza et al., 1997) despite an overall reduction in reef extent from 62m ha to 28m ha in the four years between the estimations (Costanza et al., 2014).

There is a growing trend for nature-based tourism (Balmford et al., 2009) and coupled with the fact that coral reefs and natural heritage sites are magnets for tourists (Su and Lin, 2014) it is likely that the number of visitors to South East Asia's coral reefs will increase.

The negative impacts of reef tourism, well documented in the literature, include pollution (increased nutrients; sewage; trash); consumption of reef resources (seafood and souvenirs) and direct impact by sedimentation (through unchecked coastal development), trampling and damage by boats anchoring on the reef. Between 50% and 70% of all coral reefs are under direct threat from human activities (Wilkinson, 2008). However, the causes of reef loss are a complex combination of climatic and non-climatic stresses with natural and anthropogenic components.

Rising atmospheric greenhouse gas concentrations have resulted in higher than normal sea surface temperatures (SSTs) and the frequency and extent of coral bleaching events is increasing (Hoegh-Guldberg, 1999). During such times corals and other zooxanthellate organisms such as tropical sea anemones (*Aiptasia* spp) and giant clams (*Tridacna* spp), lose their symbiotic algae and/or their pigments (Brown, 1997). Widespread coral mortality after mass coral bleaching is becoming more common (Wilkinson, 1999); in the Andaman Sea and Gulf of Thailand in 2010, mortality occurred in 42% of corals at Koh Racha Yai and 72% of colonies at Koh Tao (Chavanich et al., 2012). The loss of corals after bleaching events along with reduced reproductive output and recruitment rates (Baird and Marshall, 2002) is often coupled to changes in community structure with a shift from hard coral-dominated reefs to a community dominated by fleshy macroalgae (Hughes et al., 2007). This is particularly true for reefs experiencing increased nutrient loading [Lapointe, 1997), fishing (Hughes et al., 2007) and coastal tourism development (Bozec et al., 2008).

A shift in the zooxanthellae community composition after a bleaching event occurs in corals, increasing thermotolerance thereby improving resistance to future temperature stress (Silverstein et al., 2015), but it was Buddemeier and Fautin (1993) who first proposed that coral bleaching may be an adaptive mechanism to increased SSTs and that corals (and other zooxanthellate organisms) bleach to survive change (Baker, 2001). This may explain the observed variability in bleaching susceptibility and recovery rates of coral taxa (Marshall and Baird, 2000).

Coral reef resilience refers to the reef's ability and capacity to recover from bleaching (and other disturbance) without alteration to the

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structure or ecological function of the reef or shift to an alternate state (Curtin and Parker, 2014). The ecological resilience recognizes that the structure, function and interactions of species are important and is often described by species diversity and abundance although functional diversity and overlap (offering redundancy) is also important (Obura, 2005). The spatial resilience recognizes that coral reefs rely on the reproductive successes and connectivity of reef areas through the supply of larvae (Elmhirst et al., 2009). Healthy, diverse donor populations of corals help to maintain the resilience of downstream reef areas by supplying larvae but the availability of suitable downstream substrate is important.

Coral reefs are impacted by factors that influence ecological and spatial resilience. External factors, such as increased SSTs, require wider social and governmental policy changes to correct and will not be dealt with here. Internal factors, however, such as fishing and tourism that take place on the reef, can be effectively managed to ensure a properly functioning ecosystem and to improve reef resilience to external factors that are beyond coral reef stakeholders' control.

Marine protected areas (MPAs) are probably the most common strategy to enhance ecosystem resilience and protect coral reefs by reducing their vulnerability to internal factors. Although MPAs can not offer protection against coral bleaching, they can promote conditions necessary for recovery from disturbance (Wilson et al., 2012) thereby helping to maintain dominance of reef-building corals (Selig and Bruno, 2010). Which corals are successful will depend on the local context and extent of disturbance relative to the size of the protected area, its age and the level of enforcement (Selig and Bruno, 2010; Edgar et al., 2014).

Thailand has 12 types of marine and coastal protected areas (Nateewathana, 2010) with a total area of 78 757 km^2. There are also various laws and regulations in place involving multiple agencies and stakeholders. However, the effectiveness and the level of enforcement at these MPAs are unknown and Thailand's reefs are under increasing pressure from fishing and tourism. Nowhere is this more evident than in the coral reefs of Pattaya Bay, in the Gulf of Thailand. Chronic stress is known to reduce reef resistance and resilience to episodic disturbance such as bleaching (Carilli et al., 2009) and if the frequency of bleaching events increases because of global climate change, a tourism-impacted reef is less likely to survive intact than a reef less impacted by tourism.

Pattaya has many attractions to offer the international tourist and its islands are popular destinations for snorkeling trips judging by the number of operators offering day-trip tours. Although Pattaya has well-developed facilities for scuba diving, it is not well known for its dive sites even though it has a number of wrecks of interest and its many islands are surrounded by reefs in various states of condition – not all of them "poor". Evidence of fishing can be found on most dives and at most dive sites the signs of tourism are obvious.

The aim of this study was to assess the ways in which tourism to a privately owned island (Koh Sak) in Pattaya Bay, Gulf of Thailand threaten the integrity and resilience of its fringing coral reefs. Because Koh Sak is small it is particularly vulnerable to tourism.

The island and its reef are visited daily by many tourists, few of whom know of its rich history. In the 1960s and 70s the island was visited by Royalty, Presidents, Prime Ministers, the famous and the important including the King and Queen of Thailand, the Apollo 11 team (three months after returning from the Moon), the Commander in Chief of the Pacific during the Vietnam war and 1972's Miss World to name a few. They all left their footprints, handprints and signatures in concrete casts that now line the walkway between the north and south beaches of the island – a two minute walk. This historical aspect to the island is globally unique and overlooked by all but a few of the visitors.

To determine the impact of tourism at the island we used questionnaire surveys to define visitor demographics, their activities on the island and their willingness to pay for conservation. Coral reef condition and boat traffic to and at the island and was assessed by visual census surveys. The information will inform decision makers on how best to manage tourism to reduce negative impacts and to improve coral reef resilience in the face of climate change.

2. Methodology

All data were collected by the author with the help of undergraduate student volunteers. We applied a mixed methods approach to data collection including self-complete questionnaires, interviews, boat-traffic surveys and coral reef substrate surveys. We visited the island two times during the low (October 2013 and June 2014) and high seasonท (Nov 2013, February 2014).

2.1 Study site

The questionnaire survey of morning visitors to the island was conducted on the sandy beach of Koh Sak (12°56'36.36"N, 100°47'30.29"E) about 9km west of Pattaya and 600m north of Koh Larn. Morning visitors to the island come by speedboat as part of a package tour and typically stay for only 30-45 minutes before going to Koh Larn. Afternoon visitors, on the other hand, come by bigger, converted fishing boats and generally stay for longer; however, their numbers are much reduced compared to the mornings. There are two main reef areas at the study site (designated Station 1 and Station 2, separated by a stretch of sand. Both Stations are about 2-4m deep. Most tourism activities at the island take place over Station 1 and over the sandy area between the two stations.

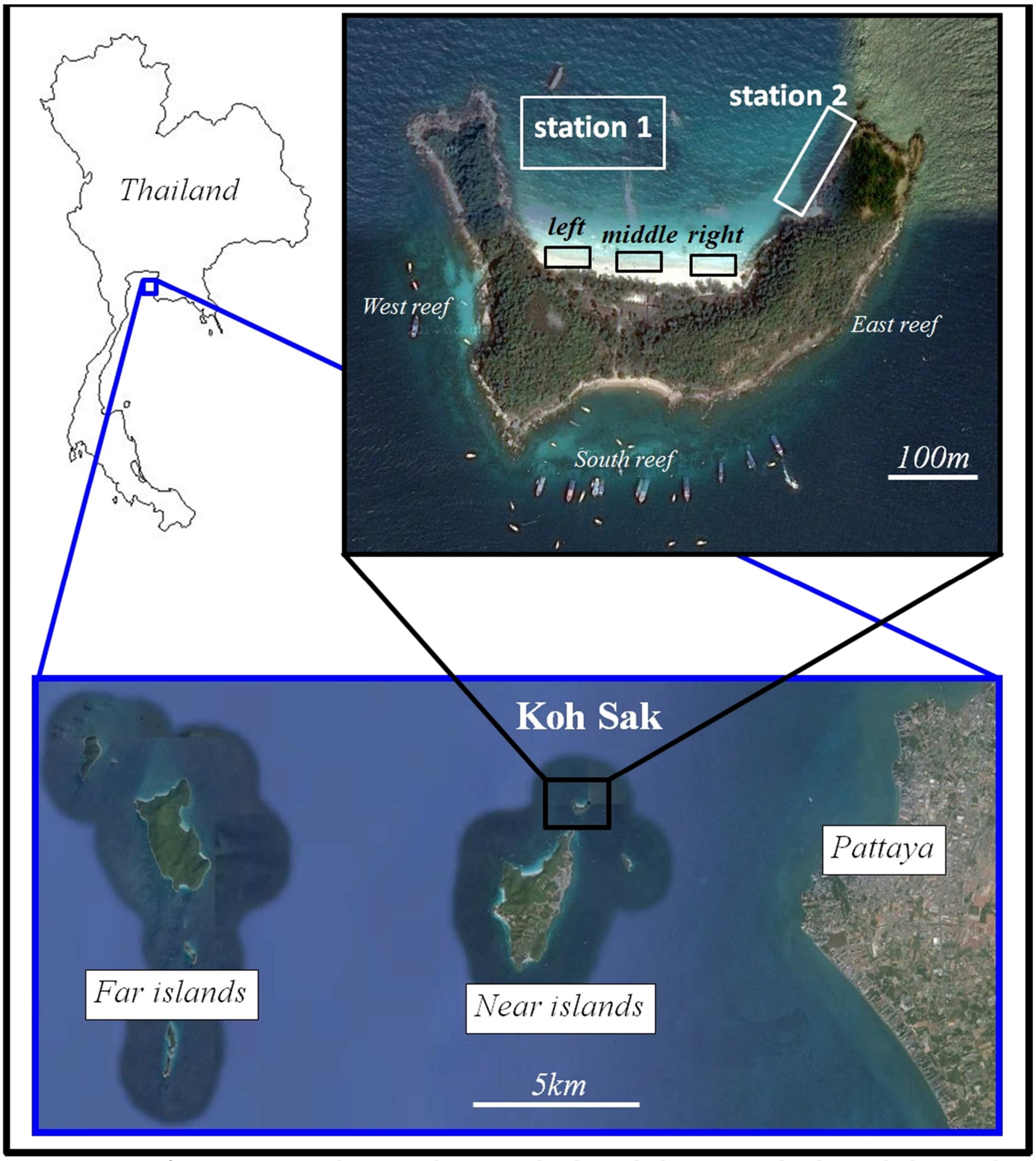


Figure 1: Map of Pattaya Bay showing the Far Islands and the Near Islands, including Koh Sak. Speedboat and jet-ski counting areas ("left", "middle" and "right") and reef substrate survey areas at stations 1 and 2 are shown. Reefs surrounding the island are indicated

2.2 Boat and jet-ski traffic surveys

We counted the number of speedboats parked at the beach and the number of boats anchored in the north bay at 30 minute intervals from 09.00 – 16.30 at each visit. No distinction was made concerning the type of anchored boat. For a 30 minute period from 10.00hrs we counted the number of speedboats arriving and leaving the beach and the number of jet-ski rides taken. To simplify counting, we recorded where on the beach the speedboats arrived and where the jet-ski rides started; the beach is about 250m long and was divided into three 50m stretches designated "left", "middle" and "right" (see Figure 1). Speedboat arrivals/departures and jet-ski rides were not counted outside of designated areas. All jet-ski riders were accompanied by a Thai jet-ski supervisor.

2.3 Visitor questionnaires

For a 30 minute period from 10.00hrs on each sampling visit, departing tourist groups were asked to self-complete a short questionnaire. Questionnaires were available in English, Chinese, Korean and Thai. The questionnaires evaluated typical demographic information (country of origin, age, gender, education, employment status and relative income), frequency of visit, participation in activities on the island and whether their tour operator provided them with any information concerning coral reefs. Visitors were asked to rate the health of the coral reef. They were also asked about their willingness to pay a conservation fee to get *on* to the island in excess of their fees to get *to* the island. The visitors were also able to write any comments relating to their experience on the island. Between 10.00-11.00hrs we gave scuba divers similar self-complete questionnaires after their dive at Koh Sak. Surveys were conducted only during the low season to minimize disruption to dive operators.

2.4 Tour guide questionnaires

Tour guides were interviewed only in the low season to obtain demographic information (age, gender), frequency of visit, number of tourists in each group and whether they provide coral reef information to visitors. We asked for their opinion on the health of the reef and whether they thought the tourists would pay a conservation fee, in excess of tour fees, to get on to the island. Guides were also asked for their general impressions of tourists and the island. Only tour guides who had been working more than one year with their present employer were included in the analysis and each tour guide was interviewed only once.

2.5 Coral reef substrate surveys

Substrate type, hard coral growth form and coral condition was recorded along two 50m transect lines randomly laid over the reef at 2-3m depth to assess benthic cover and incidence of damage. Surveys were carried out by snorkelling at two Stations (Figure 1) in February 2014. Eleven substrate types and nine hard coral growth forms (Table 1) were recorded along each transect.

Table 1: Substrate types and hard coral growth forms for substrate surveys

Substrate type	Code	Hard coral growth form	Code
Hard coral	HC	Branching	B
Recently killed coral	RKC	Corymbose	C
Dead coral	DC	Digitate	D
Rock[1]	RC	Encrusting	E
Rubble	RB	Foliose	F
Sand	SD	Massive	M
Silt	SI	Submassive	S
Soft coral	SC	Tabulate	T
Sponge	SP	Solitary	R
Nutrient indicator algae[2]	NIA		
Other[3]	OT		

[1] includes dead coral with no distinguishable corallite structures
[2] does not include turf algae
[3] includes non-reef materials such as trash

3. Results

3.1 Boat and jet-ski traffic surveys

In the high season there was already an average of 15 speedboats at the beach by 09:00hrs (Figure 2a) increasing to 27 at 10:30hrs. A similar trend existed in the low season but with fewer speedboats. In both seasons the number of speedboats at the beach decreased after 11:00hrs and by 13:00hrs only 3-4 remained. By late afternoon, only 1-2 speedboats were present (Figure 2a). There are two busy periods for anchored boats; one in the morning at 10:30hrs and the other at 14:00hrs. At the busiest period there was an average of 19 boats in bay (Figure 2b). By late afternoon this decreased to six in the high season and three in the low season. An average of 26 speedboats approached the beach in the high season between 10:00-10:30hrs and in both seasons the majority of visitors were dropped off in the “middle” of the beach (Fig. 3a). None of the speedboats that left the island between 10:00-10:30hrs (Fig. 3a inset) had arrived within the same time period. Jet-ski rides start and finish at all areas of the beach (Figure 3b) but most activity is in the “middle” with an average of 35 rides in a 30 minute period in the high season.

3.2 Visitor questionnaire response

The response rate was about 30% in the low season (n=128) but only 15% in the high season (n=199). The majority of visitors who participated in the questionnaire survey were from Taiwan (79%) in the low season and China and Korea in the high season (Table 2). More females responded than males and in both seasons visitors aged 18-34 were the largest age-group. The majority of respondents were first time visitors to the island and just over 75% of respondents in both seasons professed to being given no information concerning coral reefs during their visit to Koh Sak. Many high season visitors commented on the amount of trash at the island and the insufficient facilities (toilets).

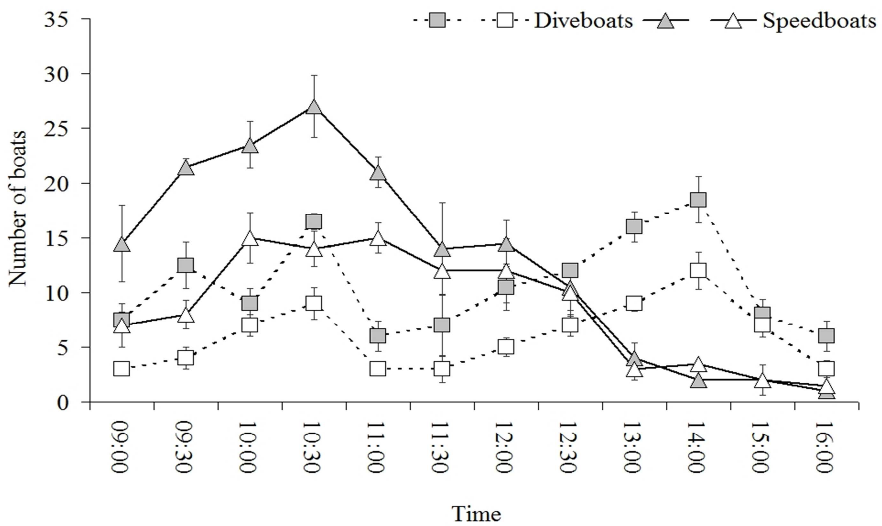
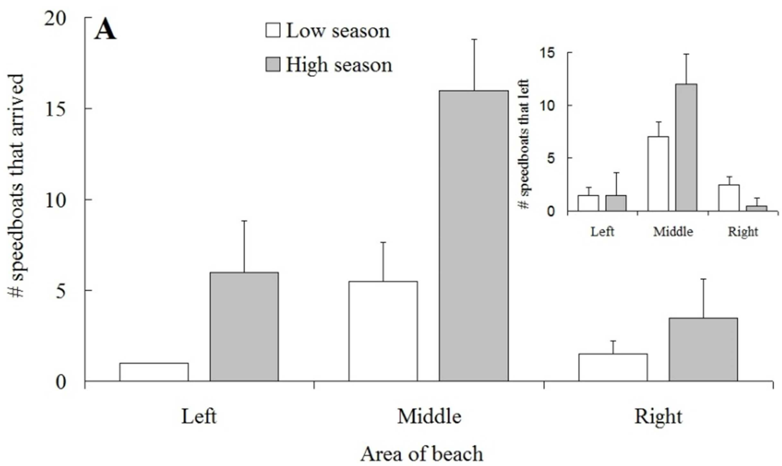


Figure 2. Number of speedboats at the sandy beach (A) and number of boats anchored in the bay (B) every 30minutes at Koh Sak



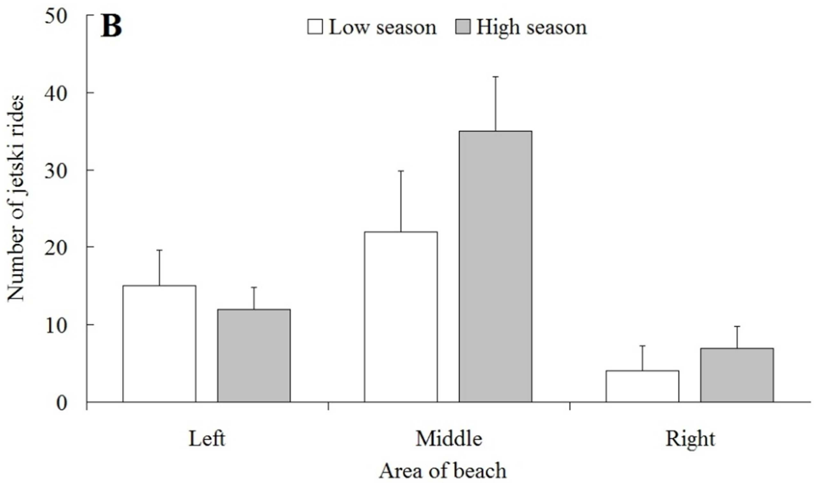


Figure 3. (A) Number of speedboats that arrived at different areas of the beach from 10:00 – 10:30hrs; inset shows the number of speedboats that left the beach from 10:00 – 10:30hrs. (B) The number of jet-ski rides taken during the same time period from the same areas of the beach.

Table 2. Koh Sak visitor profile (*low season n=128; high season n=199*)

Variable	%		**Variable**	%	
	Low season	High season		Low season	High season
Country of residence			**Highest education achieved**		
Taiwan	79		*High school*		21
China	10	53	*2 year Diploma*	7	29
Korea	5	31	*Bachelor's*	48	35
Singapore		6	*Master's*	45	15
India		6	**Relative Household income**		
Thailand	3	3	*Low*	4	9
Jordan		1	*Middle*	93	88
Bahrain	3		*High*	3	3
Gender			**Number of visits**		
Male	41	43	*One*	93	71
Female	59	57	*Two*		13
Age			*Three*		8
18-25	41	24	*>3 times*	7	8
26-34	28	38	**Coral reef information provided**		
35-40	7	19	*Yes*	24	23
41-50	17	14	*No*	76	77
51-70	7	5			
Employment status					
Employed	36	53			
Self-employed	14	22			
Not-employed		6			
Retired	4	3			
Student	46	16			

In the low season, playing on the banana-boats and jet-skis was the most popular activity (75% and 67% of respondents respectively) compared to 47% and 34% in the high season (Figure 4).

Relaxing in the shade was the most popular activity in the high season (59%) and an equal proportion of respondents played with the jet-skis, Seawalkers, swam and snorkelled (34%). Less than 5% of respondents had a ride on the glass-bottomed boat and fewer than 10% of respondents in the low season and only one in five of the high season visitors explored the island (Figure 4).

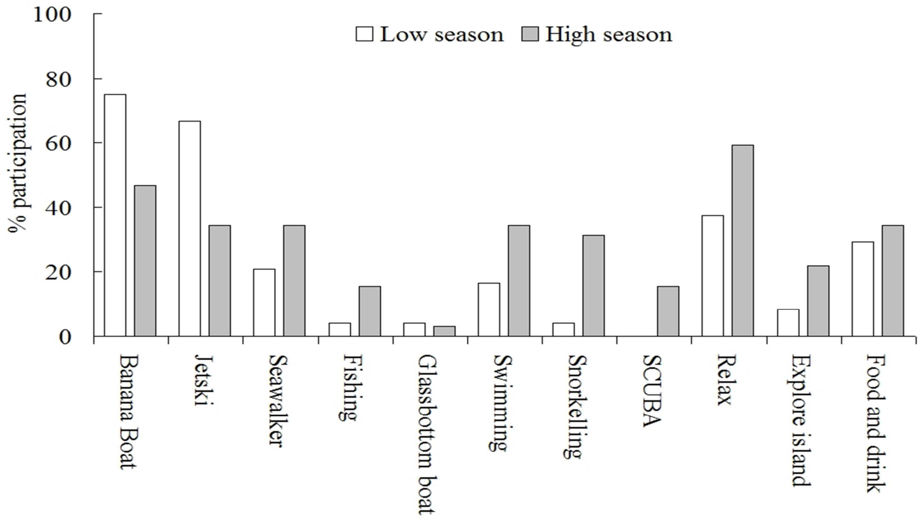


Figure 4: Visitors' stated participation in recreational activities on offer at Koh Sak

The response rate for scuba divers(n=34) was 60% and drivers from Thailand comprised 58% of the respondents, the rest coming from Europe, USA and China (Table3). Female divers were in the minority and 58% of the divers were aged 18-34.

The majority(84%) of responding divers were first time visitors to the reefs of Koh Sak and only 20% of divers received any information about coral reef(Table3). All divers complained about the jet-skins.

3.3 Tour guide questionnaire responses

The response rate for tour guides (n=27) was 60%. The tour guides we interviewed had worked an average of six years with their employers; 90% were male and 60% were aged 18-34 (Table 4). Half of the responding guides bring visitors to the island one to two times a week but 30% come every day. 86% of the tour guides bring 10-30 visitors each visit with bigger groups during the high season. Only 30% of the guides acknowledged providing coral reef information to their customers but on questioning, this information amounted only to pointing out where the reef is. Most guides considered that visitors fall into one of two types at the island; those that do the activities on offer at the island and those that relax under the shade and wait to be taken to Koh Larn.

The tour guides regard the second group as the majority of visitors to Koh Sak; our observations would agree. The jet-ski and banana boat users also fall into two main groups: the International Package Tour group, in which the cost of activities on Koh Sak, lunch on Koh Larn and their trip to Pattaya is included in the cost of their trip to Thailand; and the Local Package Tour in which the cost to the islands is paid for in Pattaya and the activities cost extra. Fee-paying jet-ski and banana-boat riders are taken around the island. The jet-ski rides around the island start on the "left" of the beach (Figure 3a).

Table 3. Low season scuba diver profile (*n=34*)

Variable	%	Variable	%	Variable	%
Country of residence		**Highest education achieved**		**Number of visits**	
Thailand	58	*High school*	38	One	84
UK	11	*2 year Diploma*	12	Two	8
USA	11	*Bachelor's*	31	Three	1
Russia	8	*Master's*	15	>3 times	7
Austria	4	PhD	4	**Coral reef information provided**	
France	4	**Employment status**		Yes	21
China	4	*Employed*	54	No	79
Gender		*Self-employed*	15		
Male	64	*Not-employed*	8		
Female	36	*Retired*	4		
Age		*Student*	19		
18-25	35	**Relative Household Income**			
26-34	23	*Low*	15		
35-40	8	*Middle*	77		
41-50	23	*High*	8		
51-70	11				

Table 4. Low season tour guide information (*n=27*)

Variable	%	Variable	%
Gender		**Frequency of visit**	
Male	90	Twice a month	10
Female	10	1-2 days a week	50
Age		3-4 days a week	10
18-25	30	Every day	30
26-34	30	*Number of visitors in each*	
35-40	30	10-20	44
41-50	10	21-30	42
Coral reef information provided		31-40	6
Yes	30	41+	8
No	70		

3.4 Perceived reef health and willingness to pay a conservation fee

Over half of respondents considered the reef "healthy" or "very healthy" (Table 5) and a third were unsure of the reef's health. Visitors in the high season were more willing to pay a conservation fee to get on to the island and 64% were willing to pay at least THB100 compared to 53% in the low season.Only 24% of tour guides confessed to being unsure of the reef's health, but

76% considered it "healthy" (Table 5). Opinions on the visitor's willingness to pay a conservation fee to get on to the island was equally divided, but of those that thought visitors would pay, 57% thought that visitors would be willing to pay THB100-200.

Half of the scuba divers surveyed considered the reef "healthy" or "very healthy" (Table 5) but 42% considered it "not healthy" or "very healthy" (Table5) but 42% considered it "not healthy" or even "dead". All surveyed scuba divers were willing to pay a conservation fee in excess of their diving costs and 77% said they were willing to pay at least THB100 to dive at Koh Sak.

3.5 Coral reef substrate

Hard coral comprised 69% of the reef at station 1 and 60% at station 2 (Figure 5a) and "massive" corals (such as *Porites*, *Platygyra*, *Favia* and *Favites*) were the dominant hard coral growth forms at both stations (69% and 90% at station 1 and 2 respectively).

Half of the "massive" corals at station 1 and 30% at station 2 showed signs of damage (Fig. 5b) and 70% of the "foliose" corals such as *Pavona* showed signs of damage at station 1. Altogether, 49% of the corals at station 1 and 26% at station 2 showed signs of damage (Fig. 5a). Broken coral rubble covered 19% of the reef at station 1 but only 5% at station 2 (Fig. 5a).

Table 5. Perceived health of the coral reef and willingness to pay a conservation fee to get on to or dive at Koh Sak.

Variable	%			
	Visitor		Tour guide[1]	scuba diver
	Low season	High season		
Perceived health of reef				
Very healthy	5	15		15
Healthy	52	35	76	35
Not healthy	10	12		35
Dead		3		4
I don't know	33	35	24	11
Willingness to pay[1]				
Yes	62	81	50	100
No	38	19	50	
Amount willing to pay (Baht)				
20	13	18	29	
50	34	18	14	23
100	33	28	43	18
200	20	29	14	32
500		7		18
>500				9

[1] tour guides were asked if they thought visitors would pay a conservation fee to get on to the island in excess of tour costs.

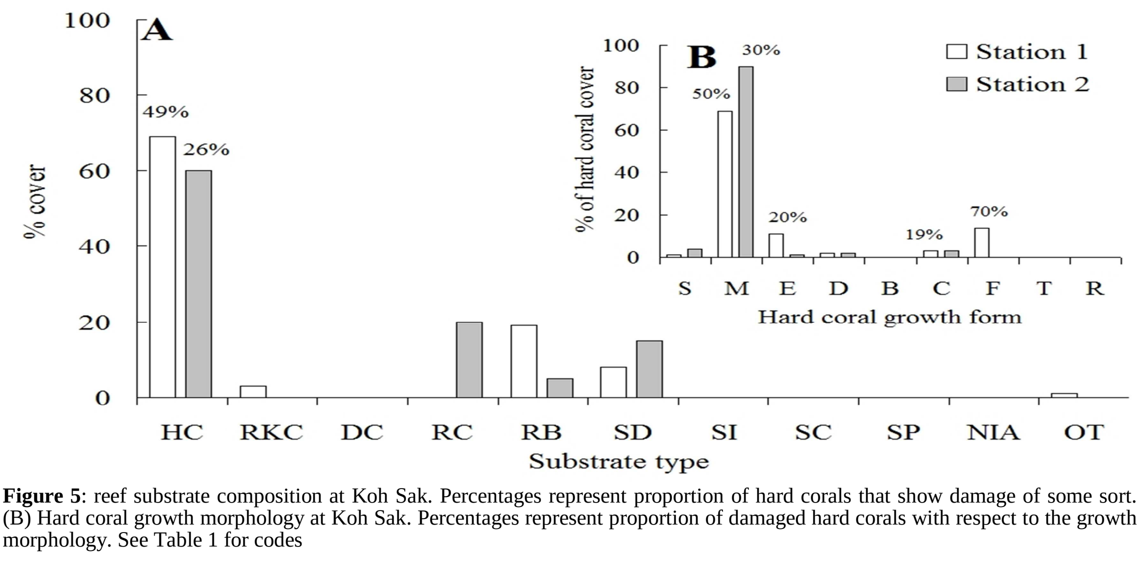


Figure 5: reef substrate composition at Koh Sak. Percentages represent proportion of hard corals that show damage of some sort. (B) Hard coral growth morphology at Koh Sak. Percentages represent proportion of damaged hard corals with respect to the growth morphology. See Table 1 for codes

4.Discussion

Freedom in a commons brings ruin to all" (Hardin, 1968).

The intensity of potential threats to the coral reefs of Koh Sak is shown in (Table 6); and coupled with the extent of physical damage at the reef reveals that present tourism at the island can be considered extractive and exploitative at best and destructive to reef integrity and resilience at worst. The pathway to the sustainable development of Koh Sak and protection of its coral reefs in the face of climate change is clear.

In the mornings, the North Bay of Koh Sak is congested with high-speed incoming and outgoing speedboat traffic and jet-skis and there is a risk of serious accident. Each jet-ski ride lasts about 30s in the high season and 45-50s in the low season (Fig. 3b) and most jet-ski rides start and end in the "middle" of the beach where most visitors are dropped off by approaching speedboats. Fee-paying jet-ski riders start their ride at the "left" of the beach, where it is quieter and along with many of the departing speedboats heading to Koh Larn, drive over the reef (station 1).

Although physical contact with the reef is likely only at lowest tides, wake generated by passing speedboats and jet-skis re-suspends and re-distributes sediments (Lenzi et al, 2013). The reef at Koh Sak is dominated by the massive coral *Porites* (Fig. 5a) and this is typical of Thai reefs (Chou et al., 1991; Yeemin et al., 2013). Many of the shallow *Porites* colonies at the island have dead areas on top and vertical growth around the perimeter of the dead part forming "micro-atolls"; this is normal in shallow waters when vertical growth is limited by exposure to air at low tide. *Porites* are relatively poor at actively rejecting sediments (Stafford-Smith and Ormond, 1992) and given that respiration rates increase (Browne et al., 2014) and photosynthesis decreases (Roder et al., 2013; Browne et al., 2014) under acute sediment stress, lateral growth of *Porites* at Koh Sak may well be restricted. The energetic costs incurred due to the mechanical removal of deposited sediments rather than its shading effects (Junjie et al., 2014) may have implications for future reef integrity and structure especially if the number of visitors increases.

Coral larvae are attracted to the acoustic cues of natural reef habitats and actively move toward the sounds of coral reefs (Vermeij et al., 2010). Boat and jet-ski noise may mask the natural sounds of the reef thereby affecting recruitment rates and given that juvenile corals are more likely to become smothered by sediment (Yeemin et al., 2013; Dikou and van Woesik, 2006), future natural regeneration of the reefs of Koh Sak is uncertain.

Little is known about the direct physical impacts of boat traffic on fish, but larval growth and development is prolonged under sediment stress implying possible effects on adult population dynamics (Wenger et al., 2013). The noise generated by boats and jet-skis has been shown to reduce auditory sensitivity and to affect acoustic communication in fish (Codarin et al., 2009). It has also been shown to affect the amount of time fish spend caring for nests and the amount of time spent in shelter (Picciulin et al., 2010) thereby possibly influencing survival through changes in foraging behaviour. Boat and jet-ski noise interferes with how reef-fish larvae react to natural reef sounds. Holles et al. (2013) showed that while only 8% of fish larvae swim away from recordings of reef sounds 44% of larvae swam away during playback of reef + boat recordings. Although reef species often show such an attraction to normal reef noises, pelagic and nocturnally emergent species actively avoid reef areas to minimize predation (Simpson et al., 2011). Any impact on the normal response of fish and larvae to the sounds of the coral reef will therefore impact recruitment and community composition.

Physical damage to the reef was extensive, especially at station 1 where 49% of coral colonies showed some form of damage and 19% of the reef was covered with coral rubble (Fig. 5a). Damage at station 2 was less because fewer people snorkel and dive there and fewer boats anchor. The damage at station 1 was caused by standing/trampling on the corals; damage by scuba divers, usually of deeper colonies; anchors from speedboats (dive boats generally anchor over the sand); and moored Seawalker-boats tying to corals. The reef would be considered a damage "hotspot" because of the high incidence of damaged corals and coral rubble (Jameson et al., 1999) but half of the interviewed divers thought the reef was healthy or very healthy. For many of the divers it was their first and only visit to the reef at Koh Sak and although no record was taken of scuba diver certification level or experience most were novice divers or "discover scuba divers (DSD)" in which visitors can try diving without getting certified. These divers are more likely to contact the reef because of lack of training and difficulties in maintaining buoyancy.

The incidence of damage and the prevalence of coral disease is greater in high use compared to low use sites at Koh Tao (Lamb et al, 2014) and the island's Scuba diving community is aware of the role it must play in the sustainable development and protection of the island's coral reefs (Wongthong and Harvey, 2014). Unfortunately, no such community exists in Pattaya yet and scuba diving is not the primary attraction to most of Pattaya's visitors. The nature and profile of the divers visiting Koh Sak, however, may be changing as more visitors "give it a try". The island's proximity to Pattaya makes it an ideal place for dive operators to bring DSDs. In order to improve resilience at the island it is necessary to provide visitors a satisfying experience without damaging the reef. Introducing a proper mooring system to preclude the use of anchors (Beeden et al., 2014) and creating alternative dive sites for novice and DSDs will reduce damage to the natural reef caused by their presence. Such practices have been introduced successfully at places such as Koh Tao. Well trained dive leaders (Barker and Roberts, 2004) committed to a Code of Conduct (Hunt et al., 2013), and a conservation-based educational dive briefing (Camp and Fraser, 2012), significantly reduce contacts with the reef and subsequent damage. Including visitors in coral reef conservation projects, according to their level of training, will promote sustainable dive tourism at Koh Sak at the same time as enhancing reef resilience.

Although the area of the reef partitioned by the Seawalkers was not surveyed, the activity undermines reef resilience at Koh Sak. Most visitors to the Seawalkers do not set foot on the island and therefore do not contribute to the island's economy. For ease of access, large colonies of interest and large fragments of corals, anemones and other reef organisms are removed from the reef and brought closer to the support-boats that supply air to the visitors underwater. The support boats and surface marker buoys, visible by satellite, are tied-off around a number of large coral colonies. We observed fishing from the support-boats, and visitors are encouraged to feed the fish for photo opportunities. Herbivorous and omnivorous fish represented 81.5% of the total abundance of fishes at nearby Koh Khangkao (Manthachitra and Sudara, 2002) and alterations to the relative abundance of functional groups, brought about by fishing and/or fish-feeding coupled with increases in nutrient concentrations (the support boats accommodate upwards of 60 people at a time and only have marine toilets), may result in increased abundance of algae and seaweeds (Ogden and Lobel, 1978) similar to the changes that have occurred in Caribbean coral reefs (Hawkins and Roberts, 2004; Bezec et al., 2008). Exposure to seaweeds results in differential gene expression in coral hosts and their associated zooxanthellae but the extent of expression is dependent on the species involved inferring that some species may be better able to challenge algal competition (Shearer et al., 2014). However, an increase in the abundance of algae may also reduce natural recruitment to the reef as fish and coral juveniles have been shown to be repelled by chemical cues from seaweeds and avoid recruiting to degraded reefs (Dixson et al., 2014).

Half of the visitors to the island considered the reef healthy and the majority of visitors revealed that they did not receive any coral reef information from their tour providers. Even though 30% of the morning visitors said they went swimming and snorkeling while at the island, no snorkelers were seen over the reef in the mornings at any of the sampling visits; it is too dangerous because of the jet-skis and speedboats. If any snorkelers were present they were in <1m water and likely to see only sand, rocks and a few fish. Less than 5% of visitors used the glass-bottom boat which provides an excellent opportunity to see the reef so one must reflect on how visitors made the evaluation that the reef is healthy. This fact may be the most troubling aspect of what happens at Koh Sak.

To a typical morning visitor at the island, the coral reef does not exist; they enjoy the sun, the golden sand and the warm water and they experience the excitement of a jet-ski ride or they relax in the shade before a fresh seafood lunch on another island. For most visitors, Koh Sak is just a stop off point before Koh Larn. If the reef was damaged beyond recovery and underwent a phase-shift the morning visitors would still come and enjoy the island and the activities on offer. Visitors to Koh Sak play an unwitting role in reducing coral reef resilience at the island and this "disconnect" must be addressed. This can only be achieved by challenging the economic model and replacing it with a business model based on conservation and education. The majority of morning visitors and all scuba divers were willing to pay an additional fee to cover the costs of island and reef conservation at Koh Sak. For coral reef conservation to be successful in providing for reef resilience at the island there must be a systematic attempt to include sustainability issues into all of the island's stakeholders' tour programmes, plans and policies. The island is small and thus provides opportunity for visitors and other stakeholders to observe both the consequences of "bad" behavior and the results of changes to that behaviour, thereby linking knowledge with action and education with conservation.

The lessons learned from the introduction of protected areas and a zoning and management plan at Koh Tao (Szuster and Dietrich, 2014), can be applied at Koh Sak.Recent surveys in and outside of the protected areas indicate that the past historical recreational use of sites was a better indicator of reef health than whether it was protected or not (Hein et al, 2015) and that the level of enforcement of rules and regulations is important. Spatial separation of competing users is typical for MPAs but at Koh Sak one must question the necessity of activities like jet-ski and banana-boat rides when they are on offer at all other beaches in the Pattaya area.

Promoting Koh Sak as a "Jet-ski -Free" island would entice more quality tourists looking for a quiet and safe beach experience. Providing transparent canoes/kayaks; switching to a solar-powered electric long-tail (Usirichun et al., 2003) glass-bottom boat; and providing ferry transport to the island instead of speedboats would limit noise, re-suspension of sediments and potential physical damage to the reef structure, integrity and resilience.

Future tourism at Koh Sak should focus on bringing visitors to the island *and* its reefs, rather than just focusing on one or the other. Koh Sak's stakeholders, in particular the Seawalkers, need to be engaged in implementing and enforcing policies, rules and regulations to protect the island and its coral reefs.

Because of its small size the task of managing threats at Koh Sak is simplified. Imposing an “entrance fee” to the island and its reefs would provide the necessary conditions and economic infrastructure and incentive to enhance the island’s cultural and natural heritage. Giving visitors something to see and do in the reef and on the island would provide a non-extractive experience that highlights the importance of coral reef conservation.

The path to knowledge and conservation-based coral reef tourism at Koh Sak should be determined by resilience research. Installation of a monitoring programme to assess reef health and integrity (Green et al., 2011) as well as a more in-depth study of the impacts of tourism on the reefs of Koh Sak is needed and is being addressed by the author. Such monitoring should include community composition, size classes, and recruitment rates of corals, fish and invertebrates. Communication of research results to visitors, diving groups and other stakeholders can determine and guide conservation efforts to ensure reef resilience in the face of climate change.

Table 6. Summary of the relative intensity of direct and indirect threats to the coral reefs at Koh Sak (* low intensity; ** medium intensity; *** high intensity)

Threat	*Noise*	*Suspended sediments*[1]	*Threat to visitor safety*	*Direct damage to reef*	*Associated impacts*
Speedboats	***	***	***	***	Speed; anchor use; fishing; smell of fuel/exhaust fumes
Jet-skis	***	* **	***	*	Discarded oil/fuel containers; smell of fuel/exhaust fumes
Scuba diving and snorkeling boats	*	**	*	**	Nutrient inputs from marine toilets and food wastes; fishing
Long-tail glass-bottom boat	**	*	*	*	Occasional groundings at low tide; smell of fuel/exhaust fumes
Seawalkers	*	***	*	***	Support boats moored to the reef; nutrient inputs from marine toilets and food wastes; trash; fishing; fish-feeding; movement of corals and other reef organisms
Island visitors	*	n/a	n/a	none	Trash; trampling on cement casts; freshwater consumption
Snorkelers	*	**	*	***	Touching/handling/collection of reef organisms
Scuba divers[2]	*	**	***	***	Touching/handling/collection of reef organisms

[1] depends on the tide; re-suspension is more likely at low tide
[2] depends on the Scuba diver’s experience, training and buoyancy control.

5. Conclusion

Koh Sak and its coral reefs represent a shared, common resource and tourism to the island is damaging the structural integrity of the reef and reducing the reef community’s capacity for ecological and spatial resilience in the face of climate change. There is a clear need to bring together local stakeholders to define and ensure sustainable coral reef tourism at the island and at other islands in Pattaya Bay. Exploitative and extractive economic practices must be replaced with a more knowledge and conservation-based industry. The lessons learned from other small islands such as Koh Tao can be applied at Koh

Sak thereby creating an infrastructure that ensures visitors participate in activities that help conserve the reef rather than weaken it.

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