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Can luxury and environmental sustainability co-exist? Assessing the environmental impact of resort tourism on coral reefs in the Maldives

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ABSTRACT

Tourism is a mainstay of the Maldivian economy, with approximately 1 million tourists a year attracted by the rich tropical marine ecosystems and the luxurious service and experience offered in the country's resorts. However, developing and running resorts to cater for tourists on relatively small and remote islands presents various environmental challenges for surrounding coral reefs. We investigated the potential impacts of tourism operations, including construction, sewage, pollution and sand pumping, on reef condition around seven islands exclusively leased for resorts. We reported variable environmental sustainability of resort practices, with some in particular being damaging. The initial construction of the resort represented an acute impact on reef condition, inferred from the lower coral cover and lower abundance of large and mature coral colonies around the newest resorts investigated. Levels of algal cover and loose sediment were higher on reef sites near the resorts, where the majority of the damaging activities take place. However, resorts activities were less important for explaining reef condition than the differences between habitats, such as the reef flat or slope, and the atoll where the resort was located. Compared to other regions globally, tourist development appeared to have less impact on reef condition in the Maldives maintaining moderately high coral cover and features of a resilient ecosystem. It is important to note that better waste management and the use of environmentally friendly infrastructure development is needed to reduce the impacts of resorts in the Maldives.

1. Introduction

Tourism provides economic benefits to tropical coastal communities and is often supported by coral reefs in terms of their aesthetic appeal and diving opportunities. A trade off exists between the impacts of tourism on coral reefs and the potential to increase economic benefits to communities (Davenport and Davenport, 2006). Globally, tourism represents the largest form of income from coral reefs compared to other uses such as fishing or coral mining (UNEP, 2006; Costanza et al., 2014) and, in many cases, in a much less extractive or destructive manner. For example within a single population of approximately 130 manta rays in the Maldives, each animal is worth an estimated $100,000 to stakeholders over the 20 years of its life, which is two hundred times the single sale value of its gill rakes for food and traditional medicine elsewhere in Asia (Anderson et al., 2011). Tourism may offer a low-impact and lucrative option for small tropical island nations to extract value from their marine resources (Miguel-Molina et al., 2014). However, if not managed properly, coastal tourism can become rapidly unsustainable with accumulated impacts on the environment from construction, transport, pollution and recreational activities (Hawkins and Roberts, 1994; Allison, 1996; Davenport and Davenport, 2006; Reopanichkul et al., 2009; Jackson et al., 2014). Degraded natural surroundings are less attractive for tourists, encouraging shifting the local tourist industry to target low cost, high volume mass-tourism, to maintain profits, which is likely to degrade the local environment further (Davenport and Davenport, 2006).

Maldives is a small island nation located in the Indian Ocean, with a native population of 350,000. The country derives a quarter of its GDP from tourism with ~1 million visitors annually in recent years, of which the most stay in all-inclusive resorts (MoT, 2015). The first resorts were established in the early 1970s in the central atolls and, since then, tourism has continued to grow (Domroes, 2001), with an annual increase in visitors of 5–20% during the past decade (MoT, 2015). From the development of the first resorts, the country has always had a policy of '1 island, 1 resort' (Domroes, 2001). This policy ensures that each resort has a direct impact on and responsibility for its immediate

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environment, removing issues of the 'Tragedy of the Commons' (Hardin, 1968) that pervades environmental issues on larger islands and continental nations. Another positive aspect of the tourism sector in the Maldives is that fishing is discouraged around resort islands in order to maintain healthy fish stocks for diving and snorkelling (Domroes, 2001). Since 2012 a 1 km radius around resort islands was legally protected as a no-take area for fishing under Boundary Regulation (Reg No. 2012/R-7).

Despite these positive aspects of tourism in the Maldives, maintaining a dense population of tourists with a luxurious lifestyle on tiny islands can be highly destructive to the fragile coral reef ecosystem that surrounds them if managed poorly (Allison, 1996; de-Miguel-Molina et al., 2014). All of the islands in the Maldives are low laying coral cays (average height < 2 m above sea level), with the majority being less than 1 km^2 in area (Sovacool, 2012). Coral cays are sedimentary islands and naturally grow, shrink and move over time, which degrades fixed infrastructures. Therefore, resorts address this natural erosion by replenishing beaches and building sea defences using sand-pumping from other part of the island (Venton et al., 2009; Zubair et al., 2011). The physical disturbance of associated with dredging and construction increase the sedimentation rate a reef, which can damage and kill corals, especially small coral recruits (Erftemeijer et al., 2012). Pollution from swimming pools, boats, sewage and waste from imported goods, comprising nutrients and other polluting molecules, can all easily enter the reef system if not carefully controlled (Reopanichukul et al., 2009; Zubair et al., 2011; Jackson et al., 2014; Peña-García et al., 2014). Increased nutrient concentration on reefs allows competitive algae to grow more rapidly, and reduces coral health and cover (Fabricius, 2005). In addition, each island must construct its own infrastructure to provide water, produce power, and deal with waste independently (Domroes, 2001; Zubair et al., 2011), which as a result of the small and physically isolated nature of Maldivian islands makes challenging and expensive to operate hotels in a sustainable manner.

There is a need to identify and manage environmental negative impacts of tourism on local environments, in order to protect both the habitats, and the tourism industry itself, from degradation. In this study, we assessed coral reef condition at various sites around seven islands exclusively leased for resorts from North Ari, Baa and Haa Alifu atolls. At each resort, benthic data were collected on different reef sites around the resort, and information about the potentially damaging activities at each resort was gathered. The aim of the study is to determine if and how much Maldivian resorts are potentially altering the associated reefs around the islands.

2. Methods

2.1. Data collection

Data were collected from 149 sites in seven resorts located in North Ari, Baa and Haa Alifu atolls between 2013 and 2014 (Table 1). A code, rather than a name, was used to identify each resort to comply with data protection agreements with partner hotels. Sites were located on reef structures found around the resorts, with the nearest sites being 50 m, and the furthest, 8 km away, from the main resort beach. The resorts included in this study enforce the no-fishing policy within 1 km of the island, so we were able to compare sites that were fished with sites that were not fished ("Fishing control", Table 1). Sites were randomly selected and stratified between the different major habitat types (Table 1). 'Slope' and 'Crest' sites were collected on the outer rim of the island at 10 m and 5 m deep, respectively. 'Flat' sites were collected behind the reef crest on the shallow (~2 m) reef platform surrounding the islands. 'Lagoon' sites were collected on isolated fringing coral formations located within the ring created by the atoll structure found at 5 of the 7 islands and were sampled at 5–10 m deep.

Information about the coral community and benthic cover of each site was collected using nine 1 m^2 quadrats arranged in line with a 5 m gap between each quadrat. In each quadrat, all corals larger than 2.5 cm were counted, identified to the genus level, and measured along their longest axis. Corals were grouped in size classes of 2.5–5 cm, 5–10 cm, 10–15 cm, 15–20 cm etc. The smallest coral colonies (< 2.5 cm) were recorded from the top left quarter (0.25 m^2) of the quadrat. Benthic cover was visually estimated as percentages of the quadrat of the following categories: hard coral cover, soft coral cover, consolidated substrate (i.e. recently dead corals and underlying limestone rock), loose rubble, sand, macroalgae, and cyanobacteria.

Observations of environmentally damaging activities were recorded while visiting the resorts and meeting with resort staff during fieldwork. In 2016, a questionnaire was sent to all resorts (Appendix 1). The questionnaires attempted to gather more information about the following four common activities observed in the resorts: sewage treatment plant outflow pipe (STP), sand pumping for beach replenishment, cleaning and maintenance of boats, and construction or dredging on the reef flat. The location, frequency and magnitude of each activity were requested, along with other relevant details of the activities. Completed questionnaires were received from four resorts (A1, B2, C1, and C3).

2.2. Resort impact indicators and reef condition metrics

Reef condition was assessed using five different metrics. 'Coral cover' (%), visually estimated from benthic quadrats. 'Algal cover' (%) was calculated as a combined percentage of turf and macroalgal cover (Smith et al., 2016), both of which increase with increasing nutrient levels in the water (Fabricius, 2005) and may have deleterious impacts on coral communities (Birrell et al., 2008). This combined metric of turf and macroalgae also recognises that on many degraded Indo-Pacific reefs the dominance of turf algae is generally more significant than that of macroalgae (Bruno et al., 2009; Jouffray et al., 2015). 'Loose sediment cover' (%) was visually estimated as the proportion of solid benthos (i.e. hard coral, algae or consolidated substrate) covered with mobile sediment (either sand or mud). The proportion of 'Big corals' in the coral community was defined as the number of colonies > 20 cm as a percentage of the total colony abundance at that site. Recruitment

Table 1
Resort information showing the atoll names, size (number of beds) and age of each resort (years since establishment). The number of sites sampled at different habitats is shown along with the number of sites protected from fishing (< 1 km from the resort) and fished sites (> 1 km).

Resort information			Habitat				Fishing control		Total Sites
Atoll (Resort)	Size	Age	Slope	Crest	Flat	Lagoon	Un-Fished	Fished	
Haa Alif (A1)	172	6 (2008)	4	3	3	0	10	0	*10*
Baa (B1)	232	8 (2006)	3	3	4	4	8	6	*14*
Baa (B2)	248	16 (1998)	3	3	4	3	7	6	*13*
Baa (B3)	130	31 (1983)	7	6	7	0	20	0	*20*
Ari (C1)	580	37 (1977)	6	7	7	4	18	6	*24*
Ari (C2)	72	27 (1987)	11	8	10	4	24	9	*33*
Ari (C3)	180	32 (1982)	9	9	11	6	18	17	*35*
Total			*43*	*39*	*46*	*21*	*105*	*44*	***149***