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## Ecological impacts and management implications of reef walking on a tropical reef flat community

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### ABSTRACT

Continued growth of tourism has led to concerns about direct and indirect impacts on the ecology of coral reefs and ultimate sustainability of these environments under such pressure. This research assessed impacts of reef walking by tourists on a relatively pristine reef flat community associated with an 'ecoresort' on the Great Barrier Reef, Australia. Heavily walked areas had lower abundances of live hard coral but greater amounts of dead coral and sediment. Abundances of macroalgae were not affected between sites. Coral-associated butterflyfish were less abundant and less diverse in more trampled sites. A manipulative experiment showed handling holothurians on reef walks had lasting negative impacts. This is the first study to show potential impacts of such handling on holothurians. Ecological impacts of reef walking are weighed against sociocultural benefits of a first hand experience in nature.

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### 1. Introduction

Coral reefs are among the most biodiverse and ecologically productive ecosystems globally (Connell, 1978) and are of high economic value in terms of goods and services (Brander et al., 2007). Associated ecosystem services of coral reefs are valued at over US\$30 billion annually (Hannak et al., 2011), and over 500 million people rely on coral reefs for provision of goods and services (Hoegh-Guldberg et al., 2007). Much of the economic activities associated with coral reefs relate to the burgeoning industry of tourism. In 2013, for example, tourism activity on the Great Barrier Reef Marine Park contributed AUD\$5.2 billion to the Australian economy, and accounted for approximately 2.09 million visitors (Deloitte Access Economics, 2013, GBRMPA 2014).

Common activities associated with marine tourism on coral reefs include water sports (e.g., parasailing and jet skiing), motor boating, recreational fishing, wildlife watching, snorkeling, SCUBA diving, and reef walking (Gladstone et al., 2013). While the ecological impacts of many of these activities are well studied, those of reef walking are less understood. Nevertheless, walking on the reef can cause breaks to coral and an increase in suspended matter, which can lead to an overall reduction in coral cover and changes to community structure (Woodland and Hooper, 1977; Liddle and Kay, 1987; Kay and Liddle, 1989; Hawkins and Roberts, 1993; Rodgers et al., 2003; Leujak and Ormond, 2008).

Long term impacts of coral decline can put the 7.5% of humanity that depend on those reefs (Barbier et al., 2011) in jeopardy.

Tourism on the Great Barrier Reef (GBR) in Australia represents both a threat and an incentive for its conservation. With approximately one third of the GBR protected under no-take zones, and activities within these areas monitored to facilitate sustainability (Osmond et al., 2010), the opportunity for tourism expanding to more pristine marine areas has arisen. Many of the resorts on the GBR advertise under the category of 'ecotourism', which is generally perceived by the public to relate to ecologically sustainable tourism, with an assumed focus on conservation awareness and minimal human impact (Bjork, 2000). One such destination is the resort on Heron Island.

Heron Island, on the Capricorn group, southern GBR, is a sand cay surrounded by a biodiverse fringing reef that is considered to be one of the more pristine fringing reefs on the GBR. A resort was established on the island in 1932 and has remained a tourist destination since then. It is now marketed as an ecotourist destination. Heron Island Resort maintains that an increase in conservation awareness in guests is achieved by promoting educational and nature-based activities, such as reef walking. Here, guests can follow educated guides on set tours, or explore the reef individually. The resort provides guests with walking shoes and poles, along with information on organisms residing on the reef flat. Guests are encouraged to pick up and handle non-dangerous marine animals such as asteroids (sea stars) and holothurians (sea cucumbers) as part of the educational experience. While education and involvement in a high-quality experience in nature can promote long-term environmental stewardship in the visitors (Ross and Wall, 1999),

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the ecological impacts of these tourists walking on the reef remain unknown.

Here we examined the ecological impacts of reef walking by tourists on the structure and composition of a reef flat on Heron Island. Specifically, we assessed the impact of this activity on the abundance of living and dead hard corals (Scleractinia), and macroalgae on the reef flat where the majority of reef walking is thought to occur (Heron Island Resort, personal communication). We predicted that the abundance of live hard corals would be lower in areas more impacted by trampling by reef walkers. As more disturbed reef flats are more predisposed to phase shifts from coral to algae (Bellwood et al., 2004), we also predicted that the abundance of macroalgae, dead coral and areas of bare sand would correspondingly increase in areas more impacted by trampling. Many species of teleosts rely on coral for sustenance and shelter, such as butterflyfishes of the genus *Chaetodon*, which feed on the hard coral (Cole et al., 2008). We thus also predicted that the abundance and diversity of butterflyfishes would decrease if the relative abundance of the live hard coral decreased. Finally, a laboratory experiment was done to assess the impact of handling stress of the most common species of holothurian on the reef flat, *Holothuria atra*. We predicted that handling stress would result in decreased rates of feeding and defecation in the holothurians, and that impacts associated with handling stress would increase with increasing handling times.

## 2. Materials and methods

### 2.1. Study site

The study was done in April 2014 on the northern fringing reef flats at Heron Island (23°30'S, 152°05'E) on the Great Barrier Reef, Australia. The reef surrounding Heron Island has varying levels of protection including Conservation Park, Marine National Park and Scientific Research

Zones. The fringing reef flat community is typical of offshore fringing reefs at similar latitudes on the GBR (Ringeltaube and Harvey, 2000; De'ath et al., 2012; Dean et al., 2015). Fringing reef on the northern side of the island occurs adjacent to Heron Island Resort and is frequented by tourists. Reef on the southern side of the island is zoned for research only and is thought to only receive minimal visitation by tourists (Fig. 1).

### 2.2. Reef walker survey

To determine the pattern of reef use by walkers near the resort, the northern fringing reef on Heron Island was arbitrarily divided into 24 grid sections using geographic landmarks, in a six by four pattern. Landmarks included large boulders on the shore, high outcrops of coral, and star picket markers used by the resort. Reef walking was offered on a daily basis by the resort. The number of reef walkers present in each grid section was recorded every 5 min by an observer on the deck area of the resort, starting 2 h before the low tide until either (a) 2 h after the low tide, (b) sunset, or (c) all reef walkers had left the reef flat. The survey was repeated during daytime low tides over five consecutive days, for at least 4 h per day. The deck area offered uninterrupted views of the entire grid area, including landmarks.

Data on the number of reef walkers were pooled across days and times, and a goodness-of-fit Poisson distribution test was used to determine if the number of reef walkers differed between sections. If differences were found between grid sections, a further Welch two-sample *t*-test was used to assess the significance of these differences. No attempt was made to identify, categorise or track individuals along their walk as it was not possible to accurately follow so many individuals over such a large expanse. It was also not possible with this design to gain an adequate estimate of the length of time reef walkers spent in a

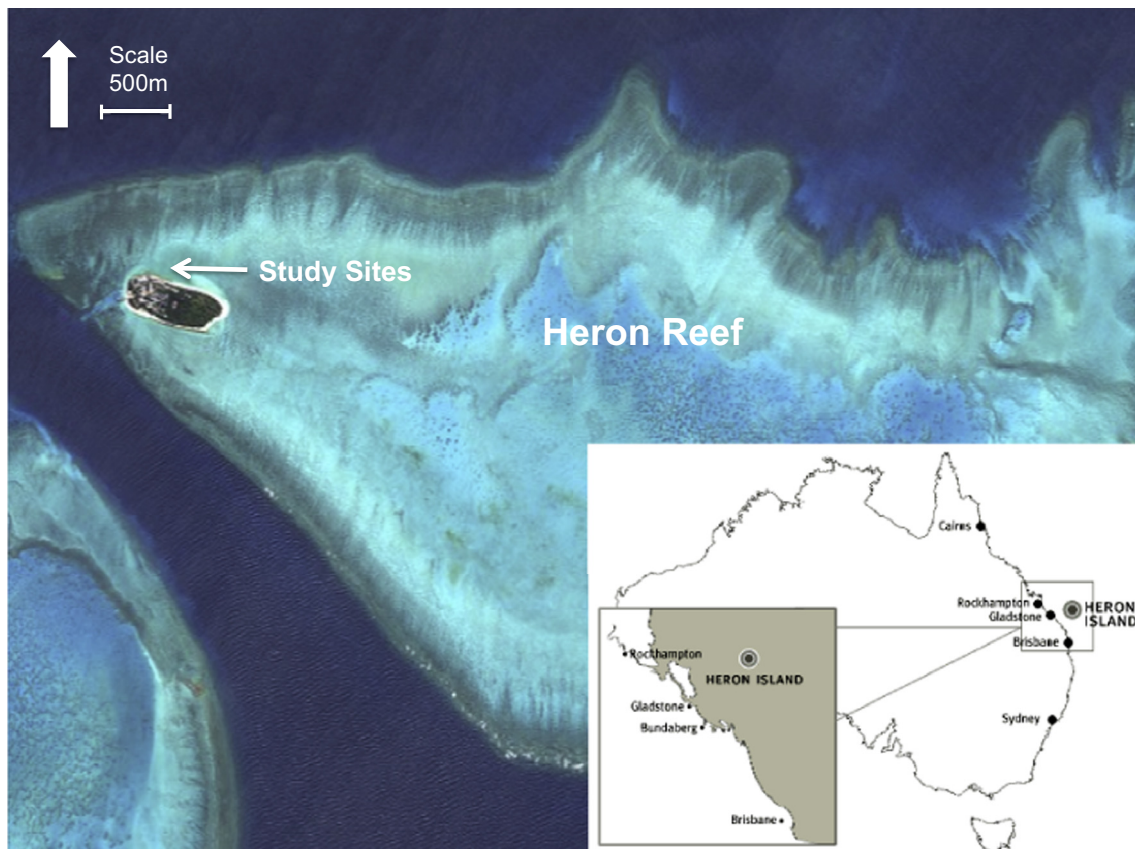


Fig. 1. Satellite image of Heron Island and the surrounding reef, and the general area of study sites designated. Heron Island Resort is located on the northern side of the island.

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