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Does use of tropical beaches by tourists and island residents result in damage to fringing coral reefs? A case study in Moorea French Polynesia

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ABSTRACT

Although coral reefs worldwide are subject to increasing global threats, humans also impact coral reefs directly through localized activities such as snorkeling, kayaking and fishing. We investigated five sites on the northern shore of Moorea, French Polynesia, and quantified the number of visitors on the beach and in shallow water. In field surveys, we measured total coral cover and colony sizes of two common genera, *Porites* and *Acropora*, a massive and branching morphology, respectively. One site, which hosted over an order of magnitude more people than the other four, had significantly less total coral cover and supported very little branching *Acropora*. In addition, size frequency distributions of both the branching and massive genera were skewed toward smaller colony sizes at the high use site. Our results demonstrated that the use of tropical beaches may result in less coral cover, with branching colonies rare and small.

1. Introduction

Over the last few decades, coral reefs worldwide have undergone loss at a dramatic rate, most likely associated with both local and global factors. It has been estimated that humans caused a 25% loss in reef ecosystems (Buddemeier et al., 2004), which are highly susceptible to environmental change (Graham et al., 2006). It is projected that over the next 50 years, the effects of increased CO_2 levels, and resulting increased temperature, alone will be enough to prevent corals from surviving (Hughes et al., 2003). In addition to increasing global temperatures commonly associated with bleaching events, increased CO_2 levels also lead to an increase in the acidity of seawater, which affects the structural integrity of the coral skeleton (Bellwood et al., 2006; Hughes et al., 2003; Jackson, 2008; Cheal et al., 2008). There is also evidence suggesting that the spread of coral diseases may be related to global climate change (Bruno and Weil, 2007; Harvell et al., 2007).

More localized phenomena such as increased nutrient input, overfishing, sedimentation and physical disturbances due to tourism and increased coastal populations also contribute to coral reef decline (Jackson, 2008; Smith et al., 2008; Hasler and Ott, 2008). Together, local and global impacts are leading to coral die offs while favoring the growth of algae (Jackson, 2008; Lapointe et al., 2005a,b; Mumby, 2007).

There is some evidence that tourism produces direct physical harm to coral through activities such as snorkeling and SCUBA diving, and that this damage may vary across coral morphological types (Hasler and Ott, 2008; Tratalos and Austin, 2001; Jameson et al., 1999). Studies have shown that there is an inverse relationship between percent coral cover and the relative use of sites; sites with a history of high use have lower coral cover (Rodgers and Cox, 2003). Another study, comparing more accessible reef flats with less accessible reef crests found a greater percent cover of bare rock and coral rubble with a lower percent cover of live coral in more accessible areas, where trampling had removed large fragments of coral (Hawkins and Roberts, 1993). Trampling also appears to affect coral survivorship, which has been found to be highest at sites visited by small numbers of people and lowest at high impact sites (Rodgers and Cox, 2003). In addition, different morphotypes of coral respond differently to physical disturbances caused by humans, with massive colonies having a higher tolerance than branching colonies. Previous research has shown that in coral reef areas primarily used for snorkeling and SCUBA diving, there has been a decrease in the ratio of branching corals to massive corals (Plathong et al., 2000).

The input of nutrients through sewage, fertilizers and other human wastes has also been shown to play an important role in reef degradation. In general, studies have found that an excess of nutrients, especially in association with additional stressors brought on by humans, impair the resilience of corals and prevent their recovery following disturbance, leading to a phase shift to algal-dominated reefs (Hughes et al., 2003; Bell et al., 2007; Lapointe et al., 2005a,b; Mumby, 2007).

The relative importance of co-occurring local factors is important to understand since many of these factors can be effectively managed within a community. Effective local management could make the difference between loss and survival of a particular reef

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or section of reef (Jackson, 2008). If relative importance of causes in decline were well known, management programs could involve public education on reef preservation or small modifications in local beach regulations. For example, many MPAs now require boats to attach to mooring buoys rather than anchoring which can damage large tracts of reef on the sea floor (Jameson et al., 1999; Dinsdale and Harriott, 2004). In French Polynesia, reefs are managed by a sub branch of the Department of Ecology Energy Sustainable Development and the Sea (MEEDDM) called The French Initiative on Coral Reefs (IFRECOR). However, the program currently does little to manage reefs and does not control the use of beaches for recreational activities on Moorea. All beaches are considered public in French Polynesia so although access to some beaches may be difficult, it is not regulated. The sites used in this study were accessible to both island residents and tourists at all times. Differences in beach usage were the result of variations in the ease of access or aesthetic desirability of a particular location.

While a fair amount of research has been done suggesting physical damage to offshore reefs is caused by tourism (Jameson et al., 1999; Dixon et al., 1993; Rouphael and Inglis, 1997), little research has focused on near shore fringing reefs, where use by humans may be even more intense due to the ease of access to these areas. Numerous studies have quantified SCUBA diver induced coral breakage at dive sites and have been able to correlate the level of damage to the popularity of the site (Allison, 1996; Barker and Roberts, 2004; Riegl and Velimirov, 1991; Hawkins and Roberts, 1993a,b; Rouphael and Inglis, 2002; Jameson et al., 1999; Medio et al., 1997; Shaalan, 2005; Zakai and Chadwick-Furman, 2002). Our study focuses on areas of fringing reef close enough to the shore and of shallow enough depth that they can be walked to from the beach.

In this study, we explored the relationship between the number of visitors on a beach and the condition of the adjacent fringing reef. Specifically, we tested the hypothesis that total coral abundance, relative abundance of branching and massive forms, and size frequency distributions within these morphotypes varied with human use. We also explored whether nutrient enrichment was associated with high human use.

2. Materials and methods

2.1. Study sites

Our research was conducted on the French Polynesian island of Moorea, 17 km northwest of Tahiti (17°S, 149°W). We chose five sites with sand beaches and adjacent (<25 m) coral fringing reefs along the north shore of the island (Fig. 1). Beaches that appeared to be either pristine or highly used were chosen to contrast the effects of human use on the reef community structure of the adjacent fringing reefs. Because all sites were located along the north shore of the island they were exposed to similar flow, wind and wave action. Although depth of corals varied between and within beaches, none were deeper than 2 m in any area surveyed to ensure corals would be shallow enough that they could be stood on. All beaches

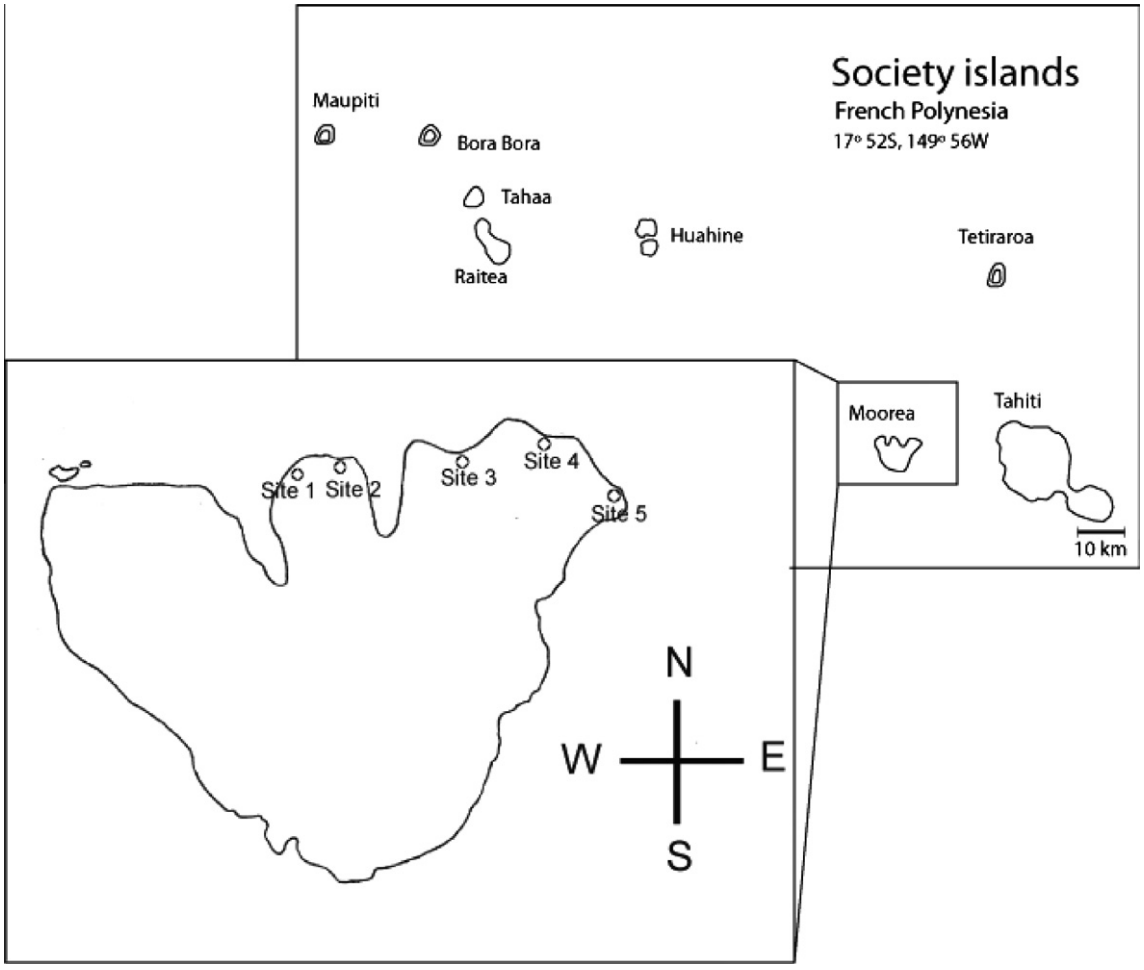

Fig. 1. Map of French Polynesia with enlarged portion showing location of study sites on Moorea. Site 1 (17°29′S, 149°51′W), site 2 (17°29′S, 149°49′W), site 3 (17°28′S, 149°48′W), site 4 (17°28′S, 149°46′W), site 5 (17°29′S, 149°45′W).