Coral-seaweed interactions and the implications for resilience of coral reefs

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Introduction

On coral reefs, coral-seaweed competition is one of the primary determinants of benthic community structure, impacting food web dynamics, topographic complexity of the habitat, and thus, biodiversity and ecosystem function (Edmunds & Carpenter 2001; Lessions *et al.* 2001; Bellwood *et al.* 2004). On modern reefs where herbivores have been overharvested, competition between corals and seaweeds becomes increasingly important, with seaweeds implicated in coral loss and ecosystem degradation (Hughes 1994; Bellwood *et al.* 2004; Hughes *et al.* 2007). Seaweeds compete with corals via multiple mechanisms (e.g. Tanner 1995; Jompa & McCook 2003; Kuffner *et al.* 2006; Birrel *et al.* 2008), but some are allelopathic to corals on contact, causing bleaching and mortality (Rasher & Hay 2010; Rasher *et al.* 2011).

On healthy reefs, establishment and survival of corals is facilitated by high rates of herbivory that suppress rapidly growing seaweeds that compete with corals (Lewis 1986, Hughes 1994; Bellwood *et al.* 2004). In recent decades, however, tropical reefs have suffered massive loss of herbivorous fishes, corals, topographic complexity, and biodiversity in general (Gardner *et al.* 2003; Bellwood *et al.* 2004). The relative roles of global change, loss in herbivores, outbreaks of diseases, etc. in generating coral loss are debated (Jackson *et al.* 2001; McCook et al. 2001; Mumby & Steneck 2008), but irrespective of the cause of reef degradation, disturbed reef ecosystems commonly convert from species-rich and topographically complex communities dominated by corals to species-poor and structurally simplified communities dominated by seaweeds (Gardner *et al.* 2003; Hughes *et al.* 2003).

The loss of species, functional groups, and critical biotic processes highlights the need to better understand key factors, mechanisms, and processes shaping coral-seaweed interactions and how these help maintain or degrade the resilience of coral reef ecosystems (e.g. Hughes 1994; Gardner *et al.* 2003; Bellwood *et al.* 2004; Bonaldo *et al.* 2009). Several studies have addressed the physical effects (shading, abrasion) of seaweeds on corals and the consequences of coral to seaweed phase-shifts that reduce reef biodiversity and structural complexity (e.g. McCook *et al.* 2001; Titlyanov *et al.* 2007), but few studies have investigated the potential of seaweeds to chemically compete against corals and the dynamics and extent of these interactions in nature. Recent studies demonstrate that some seaweeds contain allelopathic metabolites on their surfaces that cause bleaching, and sometimes death, of corals when coral are contacted by these seaweeds (Rasher & Hay 2010; Rasher *et al.* 2011). Although conducted in the field, these studies used detached coral fragments; consequences of coral-seaweed interactions for larger corals on the natural reef and over longer periods of time are still unclear.

Aims

This study aims to examine the frequency coral-seaweed contacts in fished and protected coral reefs in Moorea, French Polynesia, the effects of seaweed contact on different corals, the species specificity of these interactions, and the herbivorous fishes responsible for consumption of harmful seaweed species. More specifically, this study will respond the following questions: (1) What is the frequency of coral-seaweed contacts in the field? (2) Does this frequency differ inside and outside of Marine Protected Areas? (3) Do common corals differ in the extent of damage done by contact with different seaweeds? (4) Do rates of seaweed removal differ between fished and protected areas? (5) What herbivorous species are responsible for the removal of harmful seaweed species?

Methods

The study will be conducted on coral reefs in Moorea, French Polynesia. Three to five pairs of MPA and non-MPA reefs will be chosen for this study (*cf.* Galzin 2008, Lison de Loma et al. 2008).

Coral-seaweed contact surveys and sampling design - Benthic composition, as well as density and identity of coral-seaweed contacts will be surveyed with haphazardly placed 30m x 4m (=120m^2) transects in each study site. Along each transect, reef bottom will be photographed every 2m from a distance of 0.5 m above the benthos. Photographs will be analysed using the software Coral Point Count with Excel extension (Kohler & Gill 2006), in which 20 points haphazardly sorted by the program were placed in each of the photographs and identified.

The frequency of coral-seaweed contacts in the field will be assed with 30 additional 30 m long transects per study area. For this, all coral-seaweed contacts located within 2m of the transect line will be recorded and the interacting coral and algal species identified. Corals in contact with seaweed will be also examined for bleaching or tissue death in the area of contact. Stress of colonies of different coral species due to seaweed contact will also be evaluated with Pulse-Amplitude-Modulated (PAM) fluorometry to measure the difference in effective quantum yield (EQY) of in hospite coral zooxanthelle between colonies in contact with each seaweed species and coral without contacting seaweeds (cf. Rasher & Hay 2010).

Seaweed assays – Following the field assessments for the most harmful seaweed species in the study sites, a series of seaweed assays will be conducted to quantify variation in the removal of seaweed among study sites and MPA non-MPA reefs. Samples of three of the most harmful seaweed species to corals will be collected, brought to the research station, spin in a salad spinner for 30s to remove excess water, and the wet weight and maximum height of the thallus will be recorded. Five haphazardly selected seaweed samples of each species will be transplanted to each of the studied reefs and left for a period of 8 h. All assays will be deployed between 07:00 and 08:00 h and collected between 15:00 and 16:00 h, encompassing most of the herbivore feeding day. Within each site, one seaweed sample of each species will be placed inside a free standing exclusion cage to control the effects of handling and translocation. This procedure will be replicated three times within each study site.

Video Analysis - To identify of the herbivorous species removing the seaweeds, stationary underwater digital video cameras will be used to record feeding activity on the transplanted seaweed within each habitat. The camera will be positioned approximately 2 m from one of the four seaweed thalli of each species exposed to herbivores at each site.

Filming will commence immediately after the seaweed tahlli is attached to the reef, with a small scale bar being placed adjacent to each thallus for approximately 10 s to allow calibration of fish sizes on the video footage. Video recording will be continuous for 2 h. This procedure will be replicated three times within each site and for each seaweed species.

All video footage will be viewed and the number of bites taken from the seaweed assays by each species and size (total length, TL) of fish will be recorded. To account for body size related variation in the impact of individual bites, a mass standardized bite impact will be calculated as the product of body mass (kg) and number of bites.

Potential Outcomes

The proposed study is going to provide important information regarding the potential consequences of seaweed contacts to corals. As a consequence, the results of the present study are going to allow for an assessment of the resilience of coral reefs in Moorea, especially regarding coral-seaweed phase shifts. Also, as the study is going to be conducted in reefs with different fishing pressure, it will provide important information regarding the effectiveness of Marine Protected Areas in Moorea coral reefs.

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Financial appendix

The costs described below refer to a one-month field trip to Moorea for one research assistant and myself. Airfares will comprise our international trip from Atlanta, USA, to Moorea. The proposed study is part of a major project on allelopathic effects of seaweeds on coral colonies, which is based on Prof Mark Hay's research group. The planned costs of this project that are in excess of that provided by the IRCP – Tahiti Perles research grants will be funded by a grant National Science Foundation (NSF) (Mark Hays's project # 0929119 'Killer seaweeds: allelopathy against corals'). PAM readers and underwater video and photo cameras are currently available at Mark Hay's Laboratory. Food costs while at Moorea will be shared between my assistant and myself.

Item	Unit price (€$)	Number	Total (€$)
Aifare (ATL – Moorea – ATL)	1700	2	3400
Accomodation + research costs	45	60	2700
Total			6100