Journal of Experimental Marine Biology and Ecology 429 (2012) 15–19

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Effects of macroalgae on corals recovering from disturbance

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ARTICLE INFO

Article history:
Received 28 February 2012
Received in revised form 16 June 2012
Accepted 18 June 2012
Available online xxxx

Keywords:
Ciliates
Coral–algal interactions
Lesion healing
Macroalgae
Phase shifts

ABSTRACT

Corals have an ability to recover from disturbance through the regeneration of tissue, but macroalgae are believed to impede this process. In this study, the type of benthic macroalgae deposited on coral skeleton was manipulated experimentally, and the effects on tissue regeneration and skeletal growth of two common coral species *Acropora pulchra* and *Acropora aspera* were observed after disturbance. Macroalgae, common to the study region, but from variable functional groups, were investigated for their influence on coral growth. The green filamentous macroalga *Chlorodesmis fastigiata* significantly reduced tissue recovery in *A. pulchra*, but not in *A. aspera*. It led to the infection of *A. pulchra* with ciliates. The brown seaweed, *Lobophora variegata*, the encrusting coralline alga *Porolithon* (= *Hydrolithon*) *onkodes*, and turf algae, had only minor effects on coral recovery. This suggests that the outcome of the regeneration process is highly variable and dependent upon both, the species of coral and algae involved.

1. Introduction

Coral reefs are facing threats from ocean acidification, global warming, overfishing, and eutrophication (Hoegh-Guldberg et al., 2007). Overfishing of herbivorous fish and/or diseases of sea urchins has led to significant reductions in rates of grazing (Carpenter, 1985; Coles and Fadlallah, 1991) with consequent increases in the abundance and species composition of macroalgae (Carpenter, 1985). The increased abundance of algae may strengthen the competition with corals, particularly for space and light (Carpenter, 1985; McCook, 2001). These factors, combined with other pulse disturbances that enhance coral mortality, may shift the balance on reefs from coral-dominance to algal-dominance (Bellwood et al., 2004; Diaz-Pulido et al., 2009; Hoegh-Guldberg et al., 2007). The ability of corals to recover from disturbance, in the presence of macroalgae, is therefore a critical aspect of reef resilience and the reversal of degraded reefs to coral dominance (Hughes et al., 2007).

Coral populations can recover from disturbances by two main mechanisms: recruitment and regeneration (Pearson, 1981). Amongst the literature investigating the recovery of corals, only a few studies focus on coral tissue re-growth, and these only partially investigate the potential influence of algae on the process (Bak and Steward-Van Es, 1980; Bak et al., 1977; Diaz-Pulido and McCook, 2002; Fishelson, 1973; Titlyanov et al., 2005; van Woesik, 1998). A few studies showed that lesion healing in massive, non-branching corals was retarded in the presence of colonising macroalgae (Bak and Steward-Van Es, 1980; Bak et al., 1977; Titlyanov et al., 2005; van Woesik, 1998). However, in these studies, algal species were not fully identified and contrary to Diaz-Pulido and McCook (2002), the potential for differing responses to distinct algae was neglected. Critically, they did not isolate and experimentally manipulate the interacting algae, and therefore, the role of specific macroalgae in the hindrance of coral recovery has not been identified. Further, they did not document the potential that variation in the effects on corals can differ amongst seaweeds. The present study aimed to assess the isolated effects of different types of macroalgae on the recovery of coral tissue, after disturbance. Macroalgae, common to the region, and exhibiting a wide range of distinctive morphologies and physiologies, were investigated for their effects on a variety of coral growth parameters.

2. Materials and methods

2.1. General approach, study site and collection of corals and algae

To examine the effects of macroalgae on the regeneration of coral tissue and to observe changes in coral branch thickness, we conducted an experiment where the tissue of two coral species was partially removed and macroalgae placed on the injured area while monitoring coral growth in situ. The branching corals *Acropora pulchra* and *Acropora aspera* were chosen because they are common and abundant in the study area. The macroalgal treatment included four levels, the foliose brown alga *Lobophora variegata* (J.V. Lamouroux) Womersley ex Oliveira, the green alga *Chlorodesmis fastigiata* (C. Agardh) Ducker, the crustose coralline alga (CCA) *Porolithon* (= *Hydrolithon*) *onkodes* (Heydrich) Foslie, and turf algae, mainly the brown *Feldmannia* (= *Hincksia*) *mitchelliae* (Harvey) Kim. The four algae used are common on coral reefs and include

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doi:10.1016/j.jembe.2012.06.014

representatives of different functional form groups (sensu Littler and Littler, 1980). The erect macroalgae were collected from the reef-flat adjacent to the study site and removed together with their rhizoids (if applicable) avoiding damage to the thalli to prevent the potential leakage of chemical compounds.

The study was conducted in situ on the reef flat (0.5–3.5 m) of Heron Island Reef, GBR (23°26′S 151°52′W), during October 2007 and February 2008. The specific study site comprised an area of 250 m^2 of a reef dominated by *A. pulchra* and *A. aspera*.

2.2. Preparation of coral branches and macroalgal treatments

In order to simulate disturbance to the coral tissue, a lesion was created at the tip of the coral branches using an air pistol in situ. Healthy coral branches (>12 cm long) attached to their colonies were randomly selected for manipulation and only one branch per colony was used for this purpose. All live coral tissue was removed from the tip of each branch to a point 6 cm below the branch tip. White coral skeleton was exposed after this procedure. The shape and placement of the tissue injures were sought to imitate partial morality due to localised disturbances, such as those occurring at the study site when cold weather and rain coincide with low tides (Hoegh-Guldberg et al., 2005).

To determine whether the algae have an effect on the regeneration of injured coral tissue, macroalgae were attached to the exposed skeleton of each coral species, in such a way as to leave a 1 cm space between the attached algae and the live coral tissue on the branch (Fig. 1). This gap was left to allow time for a natural (unforced) encounter of the alga and the coral while allowing time for the coral to recover from the injuries and the alga from the transplant. As a control for coral injury, coral branches of each species were injured (as for the algal treatments), but without algae attached. To minimise colonisation by algae on the controls, injured areas were gently cleaned using a toothbrush once a week, while the edge closest to the growing coral tissue was not cleaned to avoid further injury. There were eight replicate branches per algal treatment and control, and for each coral species.

For the *L. variegata* treatment, four thalli of ca 35 cm^2 (and 0.8 ± 0.1 g wet weight each) were wrapped around the dead, exposed coral skeleton using plastic cable ties. In a pilot study, *L. variegata* thalli were readily removed by herbivorous fish. To prevent herbivory, cages were placed around each coral–*L. variegata* pair. These cages were constructed from wide mesh (2.0×1.5 cm) and thin wire to minimise impacts on flow and light, and cleaned twice a week. Parallel, unpublished experiments (D. Bender, 2008, MSc Thesis) comparing tissue regrowth in caged vs. uncaged coral branches demonstrated no significant cage effects on airbrushed corals in the absence of algae (one way ANOVA: $P = 0.124$ for tissue regeneration and $P = 0.181$ for diameter growth). For the *C. fastigiata* treatment, two tufts of 5–7 cm long and a wet weight of 3.3 ± 0.3 g each, were attached to the exposed skeleton using a cable tie. There was no need to use cages for *C. fastigiata* as no herbivory was observed over this alga during the pilot study. Four pieces of the CCA *P. onkodes* (1×1 cm) were collected using hammer and chisel, and attached to the dead part of the each coral branch with a non-toxic epoxy resin ("Knead It Aqua", Selleys®). The epoxy has been successfully used without deleterious effects on reef organisms (Jones et al., 2003). The CCA pieces were monitored for bleaching throughout the study. However, none of them showed signs of bleaching or was overgrown by other organisms. The algal turf treatment consisted of pre-existing algal assemblages naturally established on the branch tips, as the artificial attachment of turf algae proved very difficult. Coral branch tips for this treatment were selected only if the turf algae already occupied ≥2 cm of the branch tip (in all other algal treatments, branches with any turf algal cover were avoided). In this treatment, as the experimental alga was already present — only 1 cm of live tissue was required to be removed to create the gap between the filamentous algae and live coral tissue, consistent with the other algal treatments. Algal quantities were chosen to represent the approximate amount of each type of alga that would normally occur on a standard area of an experimental *Acropora* branch surface, ca 40 cm^2. The experiment ran for 15 weeks.

2.3. Length and diameter measurements

Measurements were taken at the beginning (23rd October 2007) and at the end of the experiment (5th February 2008). A reference cable tie was placed at a distance of ≥5 cm away from the lesion edge. Tissue accretion/loss was determined by measuring the distance between the cable tie and the tissue lesion border (Fig. 1). The

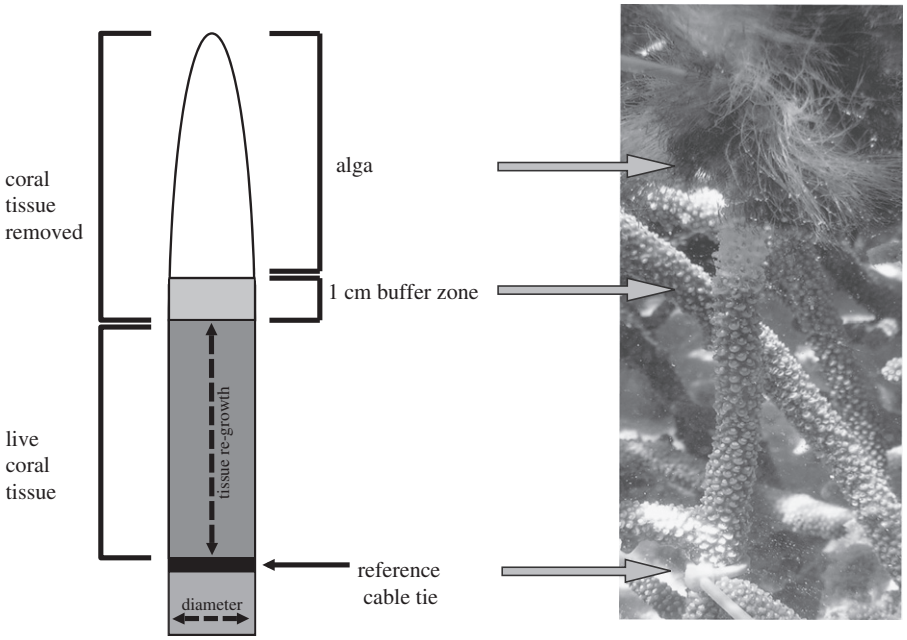

Fig. 1. Preparation of treatments. Coral branches were cleared of 6 cm of tissue at the tip and the algal treatments were attached 1 cm away from the lesion. A reference cable tie was attached at the bottom of the branch (≥5 cm away from the lesion).