Corals striking back; no effects of the red seaweed *Eucheuma denticulatum* on coral health in a tropical reef environment

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**Background**

Coral reefs are rapidly disappearing globally and a greater understanding about the factors impacting them negatively is urgent. Invasive seaweeds have shown to alter coral reef habitats by causing phase shifts from a coral to a macroalgal dominated state with severe negative ecological effects and dramatic coral reduction. Herbivory has been documented to buffer these changes, but top down control of non-native seaweeds is less common as many herbivores prefer native species. In Tanzania, South-east Asian fast-growing strains of the macroalgae *Eucheuma denticulatum* have been introduced through seaweed farming practices. As this species also occurs naturally in the Western Indian Ocean (WIO), an ongoing introduction as well as potential negative ecological consequences are difficult to detect. However, recent studies using molecular methods have shown that South-east Asian *E. denticulatum* dominate wild eucheumoid populations around Zanzibar (Unguja) Island, potentially altering the herbivore top down control of macroalgal densities. Further, South-east Asian *E. denticulatum* are documented to overgrow and outcompete reef-building corals in other geographical locations. If this is also the case in the WIO area is unknown. In this study we investigated interactions between *E. denticulatum* and reef building corals on Unguja Island, Zanzibar, in the presence and absence of herbivores. Further, we investigated if *E. denticulatum* prefer to grow on live or dead *Acropora* sp. to evaluate if it is the structural complexity itself rather than coral tissue that provides a suitable habitat. This was done by studying growth rates and holdfast development in introduced and native *E. denticulatum* on i) live and dead branches of *Acropora* sp. and ii) in the presence and absence of herbivores. Additionally, we estimated coral and macroalgal health between treatments.

**Methods**

The study was performed during 28 days in Jambiani, southern Zanzibar (Unguja), Tanzania, (S6° 18.701' E39° 33.547") between October and November 2018. To investigate the effects of macroalgae (*E. denticulatum*) overgrowth on coral and growth substrate preference (live or dead coral) of *E. denticulatum*, fronds of macroalgae were tied to 20 living and 20 dead colonies of *Acropora* spp. Further, the potential effect of herbivory by fishes and urchins was tested by covering 20 of the samples with herbivore exclusion cages. **Coral health** was
estimated at the start of the experiment and thereafter once a week until experiment termination. Visual inspections and Pulse-Amplitude-Modulation (PAM) fluorometry were used to detect stress on each coral sample (e.g. bleaching, discoloration of tissue). At the termination of the experiment, all coral colonies were measured (height), photographed and visible bleaching effects or scars were noted. Coral health status was estimated according to a 5 degree scale where 1 = no visual effects of discoloration, bleaching or scars and 5 = completely bleached with necrotic tissue. The macroalgae were carefully removed and the location of attachment (on living coral, coral peg or dead coral) and status of attachment (not attached/attached) was noted. Samples were weighed and photographed and health status was estimated according to the same 5 degree scale used for the coral samples. Molecular analysis using mitochondrial cox2-3 spacer was used to separate introduced (South-east Asian origin) from indigenous individuals (East African origin). To estimate herbivore pressure a standardized point count census method for fish was conducted where fish abundances were visually investigated. Fish surveys (N=20) were conducted in the vicinity of the experimental site (within a radius of ~200 m). All fish were identified to the lowest taxonomical level possible and feeding guild was assigned to each species using FishBase.

Results

No significant effects on coral health by South-east Asian or East African E. denticulatum were found when measured by PAM (ANOVA; f-value = 0.229, df = 2, p > 0.05) or visually estimated (ANOVA; f-value = 1.81, df = 2, p > 0.05). Further, when investigating if E. denticulatum prefer to grow on live or dead Acropora sp, no effects on macroalgae biomass was found. However, the stress response was significantly higher in algae exposed to live than dead coral (Kruskal-Wallis rank sum test, chi-square = 16.425, df = 1, p < 0.001). No algae were able to attach to live coral but did attach to dead coral and coral mounting pegs. Herbivory was the only factor that significantly impacted biomass of E. denticulatum; biomass loss was significantly higher in open treatments compared to closed ones (ANOVA; f-value = 61.93, df = 1, p < 0.0001). Inventory studies on fish assemblages showed that macroalgal feeding species (such as Siganus spp. and Naso brevirostris) were present.

Conclusion

Algae did not attach to live coral and coral health was not impacted by the presence of E. denticulatum, nor by algal origin (introduced vs indigenous). The biomass of E. denticulatum did not differ depending on substrate (live or dead corals) but algae health was negatively impacted by interactions with live coral. The biomass of E. denticulatum was influenced by herbivory; fronds exposed to herbivores had a lower biomass than caged fronds. The present study shows that E. denticulatum does not pose a strong threat to live corals. However, shading effects and potential competition for space by coral recruits in areas with dense populations of E. denticulatum needs further investigation. As herbivory is shown to be an important factor in reducing macroalgal biomass, it is important to maintain large and viable populations of macroalgal feeding fish.