# UNDERSTANDING THE FUNCTIONAL ROLES OF BIODIVERSITY IN THE GALÁPAGOS MARINE RESERVE, ECUADOR.

## INTRODUCTION

While exact rates of species extinctions are difficult to determine, there is a consensus that they are alarmingly high, motivating the need to understand the functional roles of biodiversity. In response to this need, we have seen an increasing number of studies in the last decade that aim to understand the potential consequences of biodiversity loss on ecosystem functioning. The general pattern is that biodiversity has a positive effect on a variety of ecosystem functions. Synthetic reviews and consensus reports on Biodiversity and Ecosystem Functioning (BEF) marine studies have identified two general information gaps. *First*, the vast majority of biodiversity and ecosystem functioning research has focused on species that have no risk of local or global extinction. Marine communities are rapidly losing populations, species or entire functional groups, due to overfishing and climate change. This loss has provoked dramatic shifts in community structure and has compromised the services that biodiversity provides to human beings. Consequently, it is important to conduct BEF studies with real extinction scenarios. *Second*, 95% of BEF studies have been performed in mesocosms under environmental conditions that likely differ from those in natural habitats. Although such studies provide useful insight about potential relationships between biodiversity and ecosystem functioning, the few BEF studies conducted in natural systems (*in situ*) have revealed different outcomes or stronger effects of biodiversity on ecosystem functioning. Since *in situ* studies are more representative of the natural world, additional factors influencing the relationship between biodiversity and ecosystem functioning could be uncovered.

Several studies consider sea urchins important species because of their dominant effect on the structure of marine communities. Urchins have the potential to influence the distribution, relative abundance and species composition of algae and other sessile invertebrates, determining the biomass, diversity and productivity of marine communities. Urchin populations in the Galápagos Marine Reserve can easily reach densities of 30 individuals per m2, thus they represent one of the most important group of grazers in the ecosystem. Of the 19 urchin species reported, *Eucidaris galapaguensis*, *Lytechinus semituberculatus* and *Tripneustes depressus* comprise 91% of the total urchin biomass in the Galápagos Islands. Of these, *Tripneustes depressus* is locally consumed and might become a fishing target in the near future. The purpose of my study was to understand the functional roles of urchins in a natural, marine system.

## METHODS

The number and composition of *Eucidaris galapaguensis*, *Lytechinus semituberculatus* and *Tripneustes depressus* was manipulated in inclusion cages from December 2007 to January 2008 at Caamaño Island in the central Galápagos archipelago at 10 m depth (Fig 1, left). The experimental unit consisted of a circular cage (0.5 m² area) made of plastic coated steel mesh (Aquamesh TM) bolted to the rock substrate by drilling (Fig. 1, right).

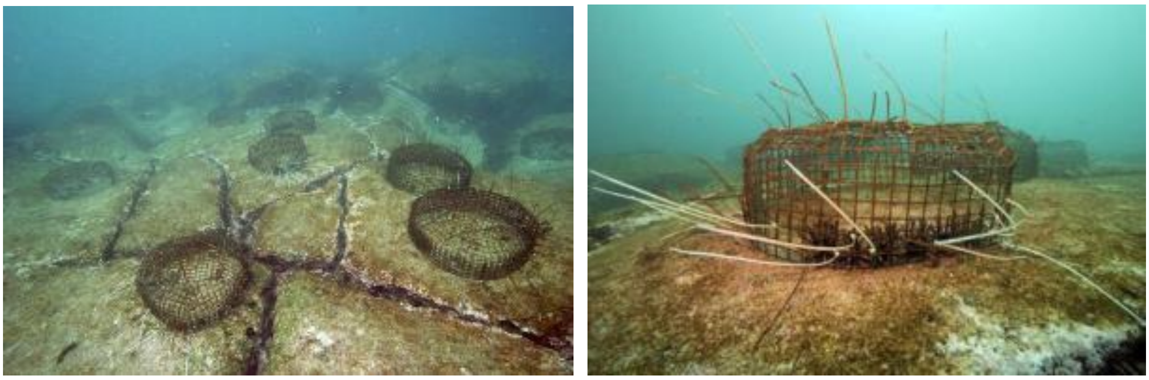

**Figure 1** Experimental set up at Caamaño (left). Experimental unit showing a one species treatment (right).

There were three levels of species richness: one, two and three species. Each urchin species composition was replicated five times (Table 1). Urchin density was held constant at six individuals per cage, which is within the range of natural densities for these species in the Galápagos.

**Table 1** Experimental design to test the effects of urchin diversity on algal abundances.

| Treatment (# of urchin spp) | Urchin species composition |
|---|---|
| 0 | Control Cage (CC) x 5 reps |
| 1 | *Eucidaris galapaguensis* (E) x 5 reps |
| | *Lytechinus semituberculatus* (L) x 5 reps |
| | *Tripneustes depressus* (T) x 5 reps |
| 2 | E+L x 5 reps |
| | E+T x 5 reps |
| | L+T x 5 reps |
| 3 | E+L+T x 5 reps |

Change in the cover of benthic algae (% grazed) was determined as the response variable. Control cages lacking urchins were employed to ensure that a change in the algal % cover within treatments was due to grazing. The entire area of the rock substrate within each cage was photographed before and after including the urchins in the cages. The images of the photos taken in the field were analyzed in Photoshop. Then, tests of analysis of variance (one-way ANOVA) were applied to detect differences between the different levels of species richness and controls. Caging can create potential artefacts, reducing available light and food supply within the cage due to the overgrowth of algae and epifaunal invertebrates on the surface of the cages. To reduce these artefacts, the experiment was maintained every other day by brushing these organisms off the cages.

Species-specific traits such as attachment strength can determine an urchin's ability to graze, because they need to hold themselves to the substrate while feeding. For this reason, I collected for each urchin species data on the forces (attachment strengths) necessary to dislodge them from the rock substrate. The procedure consisted of tapping individuals on their aboral surface to stimulate the attachment of their tube feet. Next, an urchin grabber device was placed around the urchin's test, forming a harness. A force gauge (Wagner Instruments, FDN 100) was attached to the harness and then carefully pulled perpendicular (90°) to the substratum until the individual was detached (Fig. 2).
Then, the force was recorded to the nearest Newton (N).

**Figure 2** Data collection on attachment strengths.

**RESULTS**

The initial conditions of the substrate were similar in terms of the mean % cover of algae before including the urchins in the cages (one-way ANOVA, p=0.698). On average, the substrate within all treatments had a cover of 95% algae and epifaunal invertebrates. At the end of the experiment, the % cover of algae did not change significantly in the control cages (92%), which means that any possible caging artefact was ruled out and that any reduction of algae on the diversity treatments was due to urchin grazing.

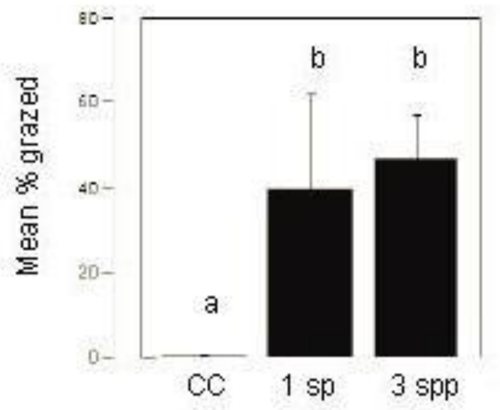


**Figure 3** Mean % grazed algae between treatments (CC: Control Cage; 1 sp: average single species treatments). Different letters mean significantly different groups. N=3 (two pending replicates to analyze) Error bars: +/- SE.

I found a significant effect between treatments and controls (one-way ANOVA, p=0.005). Although there was a trend of increasing % grazed when urchin richness increased from one to three species, post-hoc Tukey tests revealed that these two groups were not significantly different (Fig. 3). This means that the three species together grazed as much as the average of the single species treatments. The overall significant difference is due to the contrast between the almost zero-grazing in the control cages and the other treatments (Fig. 3).

Figure 4 shows the significant effects by individual urchin species (one-way ANOVA, p=0.001). Post hoc Tukey tests revealed the idiosyncratic effect of *Tripneustes depressus*. After five weeks, *T. depressus* grazed more than 80% of the substrate, while *Lytechinus semituberculatus* and *Eucidaris galapaguensis* grazed only around 17% (Fig. 4). These results are particularly interesting, as *T. depressus* is the only urchin species that is harvested for local consumption in the Galápagos Islands and due to the continuous fisheries collapses (sea cucumber, lobster and sea bass) it might be a fishery target in the future.

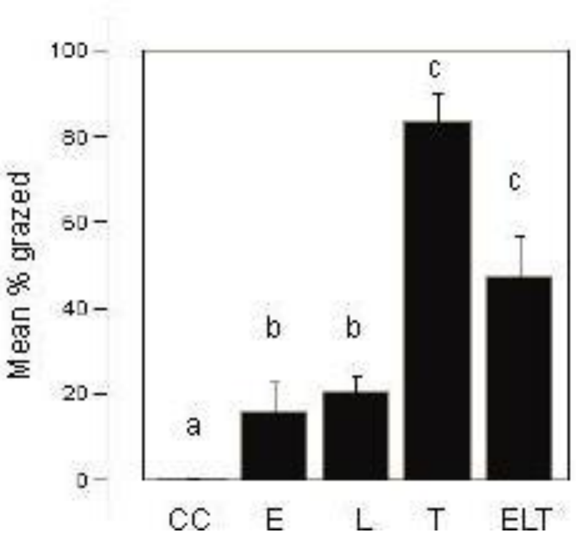


**Figure 4** Mean % grazed algae between all treatments (CC: Control Cage; E*: Eucidaris galapaguensis*, L: *Lytechinus semituberculatus*, T: *Tripneustes depressus*.
Different letters mean significantly different groups. N=3 (two pending replicates to analyze) Error bars: +/- SE.

Preliminary data showed that *Tripneustes depressus* has a greater attachment strength (one-way ANOVA, p=0.003) than the other two urchin species (Fig. 5). However, these comparisons are based on a low numbers of measurements so more replicates are needed to adequately test the hypothesis.

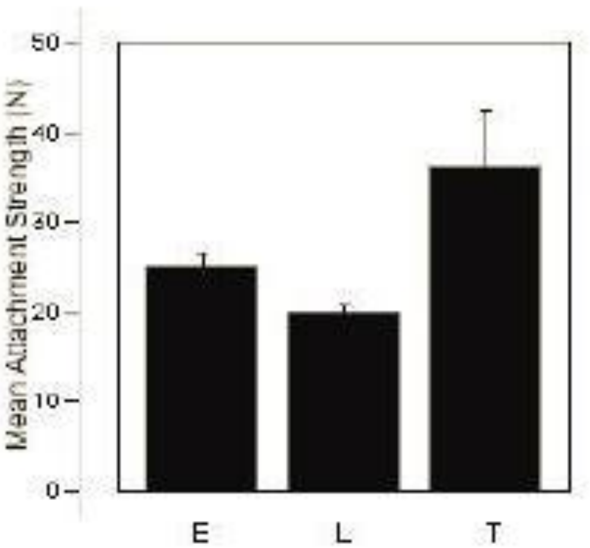


**Figure 5** Mean Attachment Strengths (N=Newtons) for the three urchin species. E: *Eucidaris galapaguensis*; L: *Lytechinus semituberculatus*; T: *Tripneustes depressus*. N=5. Error bars +/- SE.

**CONCLUSIONS**

I determined that *Tripneustes depressus* is the most important grazer between the 3 most common urchin species in the Galápagos Marine Reserve. Kept in relatively small densities, urchins are crucial in removing algae from the substrate, which is an essential process for subordinate algae species or other invertebrate species to colonize and increase the diversity of marine communities. Secondly, my data on attachment strengths suggests that the reason of why *Tripneustes depressus* has this overwhelming effect is because its ability to forage under high flow conditions. Thus, having identified how and why this urchin species matters has important implications for the maintenance of diversity in the Galápagos Marine Reserve.