Supplemental Data Phase Shifts, Herbivory, and the Resilience of Coral Reefs to Climate Change

Terence P. Hughes, Maria J. Rodrigues, David R. Bellwood, Daniela Ceccarelli, Ove Hoegh-Guldberg, Laurence McCook, Natalie Moltschaniwskyj, Morgan S. Pratchett, Robert S. Steneck, and Bette Willis

Supplemental Experimental Procedures

Sublethal Impacts on Corals

Tissue thickness, an indicator of coral biomass and energetic reserves [S1], did not differ among colonies of *Porites cylindrica* inside or outside cages provided that they were not in competition with algae (1.80 ± 0.06 [S.E.] and 1.82 ± 0.12 mm, respectively). However, colonies in cages that were shaded or partially overgrown by



macroalgae had thinner tissues $(1.45 \pm 0.11 \text{ and } 1.15 \pm 0.10 \text{ mm}$, respectively), a reduction of 22% and 36% (F = 4.55, p < 0.05). Similarly, the reproductive output of experimental fragments of *Montipora digitata* transplanted into cages and placed beneath algal canopies declined by half compared to adjacent, unshaded controls inside and outside of cages. Egg size, the number of eggs per polyp, and number of reproductive polyps per cm² of tissue all declined in coral fragments placed beneath algal canopies (by an average of

Figure S1. Biomass of Herbivorous Fishes Plotted against Body Length for Three Experimental Treatments

(A) Cages that excluded medium- and largesized fishes.

(B) Partial cages that remained accessible to fishes of all size.

(C) Open plots.

The fish-exclusion cages worked very effectively at keeping out medium and large fishes. reducing the biomass of herbivorous fishes by close to an order of magnitude lower than the partial cages or open plots (Figure 3, F = 7.79, p < 0.001). Fishes greater than 15 cm standard length were virtually absent from the cages, yet they comprised greater than 80% of the biomass in the two other experimental treatments. Although they made a negligible contribution to biomass, juvenile parrotfishes recruited readily into the cages and were four times more abundant there at the end of the experiment than elsewhere. The biggest fish (>30 cm), primarily roving scarids and acanthurids, accounted for approximately half of the total herbivore biomass in partial cages and open plots. Their mobility, schooling behavior, and relatively low numbers (compared to copious numbers of smaller recruits) account for the large standard errors around the average biomass. The similarity between the partial cages and open plots is striking, indicating that the former allows unhindered access to fishes. Error bars are SE.



Figure S2. Canonical Discriminant Analysis Showing the Successional Changes in Macroalgal Composition

Each red circle (i.e., centroids with 95% confidence limits) indicates the taxonomic composition inside fish-exclusion cages, at 13 times over the course of the experiment (units are in months). The blue circle encompasses all centroids for algal assemblages inside the partial cages and open plots at each of the sampling periods, indicating that these two treatments are very similar and did not change over time. The first two axes in the CDA explain 73% of the variation among treatments and times, confirming the rapid successional changes in macroalgal assemblages within the cages. An initial bloom in the first 6–12 months was dominated by fast-growing *Padina* (ANOVA, F = 5.74, p < 0.001), with smaller amounts of *Hydroclathrus* (F = 5.26, p < 0.0001) and a diverse range of other taxa. Subsequently, massive stands of *Sargassum* became dominant in cages until the end of the experiment (F = 5.58, p < 0.001; Figure 1B). Beneath the *Sargassum* canopies, a speciose understory flora developed, including *Padina*, *Labophora*, *Hypnea*, *Turbinaria*, and *Peysonnelia* crusts. On the Great Barrier Reef, fleshy algae such as *Padina* and *Sargassum* are generally abundant only on near-shore reef flats, widely recognized as a spatial refuge from herbivorous fishes [S2, S3], and absent from heavily grazed reef crests (the location of our experiment) where epilithic algal turfs (<10 mm tall) and coralline crusts predominate. Once the mesh was period of 3–4 weeks as the flora converged once more toward the heavily grazed partial cages and open plots.

9.5%, 10.2%, and 25.8%, respectively) and thus yielded an overall decline in reproductive output of 45% compared to controls (F = 5.04, p < 0.01).

Supplemental References

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Figure S3. Cover of *Porolithon onkodes*, in the Three Experimental Treatments, after 26 Months

Total coralline cover fell by 19% in the cages compared to a smaller loss of 5% in the partial cages and a gain of 9% in the open plots. By the end of the experiment, the dominant herbivore-resistant Indo-Pacific species, Porolithon onkodes, was 40% less abundant inside the cages compared to elsewhere (ANOVA, F = 7.2, p < 0.05), whereas a suite of cryptic, understory taxa became increasingly prevalent beneath the growing canopy of fleshy seaweeds. Foliose Mesophyllum purpurescens (Figure 1C) accounted for 24% of coralline cover below the macroalgal canopy in the cages but was virtually absent elsewhere. The decline and taxonomic shift of corallines, which mimics similar trends on degraded and overfished reefs, are significant because of their role in promoting reef accretion and coral settlement [S4]. Error bars are SE.