

### In this review:

- A. Recent articles – no abstract available
- B. Recent articles with abstracts

## A. Recent articles – no abstract available

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Jayewardene, D. and Birkeland, C. **Fish predation on Hawaiian corals.** *Coral Reefs* 25(3): 328, 2006.

Miller, J., Waara, R., Muller, E., and Rogers, C. **Coral bleaching and disease combine to cause extensive mortality on reefs in US Virgin Islands.** *Coral Reefs* 25(3): 418, 2006.

Dalton, S.J. and Godwin, S. **Progressive coral tissue mortality following predation by a corallivorous nudibranch (*Phestilla* sp.).** *Coral Reefs* 25(4): 529, 2006.

Goodwin, E.J. **Conservation of coral reefs under the Ramsar Convention on Wetlands.** *Journal of International Wildlife Law and Policy* 9(1): 1-31, 2006.

## B. Recent articles with abstracts

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Berkelmans, R. and Van Oppen, M.J.H. **The role of zooxanthellae in the thermal tolerance of corals: a 'nugget of hope' for coral reefs in an era of climate change.** *Proceedings of the Royal Society B* 273(1599): 2305-2312, 2006.

**Notes:** The ability of coral reefs to survive the projected increases in temperature due to global warming will depend largely on the ability of corals to adapt or acclimatize to increased temperature extremes over the next few decades. Many coral species are highly sensitive to temperature stress and the number of stress (bleaching) episodes has increased in recent decades. We investigated the acclimatization potential of *Acropora millepora*, a common and widespread Indo-Pacific hard coral species, through transplantation and experimental manipulation. We show that adult corals, at least in some circumstances, are capable of acquiring increased thermal tolerance and that the increased tolerance is a direct result of a change in the symbiont type dominating their tissues from *Symbiodinium* type C to D. Our data suggest that the change in symbiont type in our experiment was due to a shuffling of existing types already present in coral tissues, not through exogenous uptake from the environment. The level of increased tolerance gained by the corals changing their dominant symbiont type to D (the most thermally resistant type known) is around 1-1.5°C. This is the first study to show that thermal acclimatization is causally related to symbiont type and provides new insight into the ecological advantage of corals harbouring mixed algal populations. While this increase is of huge ecological significance for many coral species, in the absence of other mechanisms of thermal acclimatization/adaptation, it may not be sufficient to survive climate change under predicted sea surface temperature scenarios over the next 100 years. However, it may be enough to 'buy time' while greenhouse reduction measures are put in place.

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Quan Young, L.I. and Espinoza-Avalos, J. **Reduction of zooxanthellae density, chlorophyll a concentration, and tissue thickness of the coral *Montastraea faveolata* (Scleractinia) when competing with mixed turf algae.** *Limnology and Oceanography* 51(2): 1159-1166, 2006.

**Notes:** We evaluated the effects of competition for space between mixed turf algae (MTA) and the hermatypic coral *Montastraea faveolata* Ellis and Solander (1786) using reciprocal transplantation of 17 cm<sup>2</sup> cores and by measuring the response of some biological parameters of the coral: zooxanthellae density, mitotic index, chlorophyll *a* (Chl *a*) concentration, and tissue thickness. Mitotic index and Chl *a* zooxanthellae<sup>-1</sup> were not significantly affected by the competition, but zooxanthellae density, Chl *a* cm<sup>-2</sup>, and tissue thickness were reduced in *M. faveolata* tissue surrounded by algae. Lower values have been reported for these three biological parameters of scleractinian corals subjected to stress conditions. Stressed *M. faveolata* surrounded by MTA were completely overgrown in 6-9 months. MTA frequently formed unattached cushions before the algae were attached to the coral skeleton. The cushions could be affecting *M. faveolata* by shading the coral tissue beneath the algae and probably causing stress to the tissue. Trapped sediments in the cushions may also be affecting *M. faveolata* by trapping sediments that cause smothering or burial of coral tissue. This is the first demonstration that algae directly stress a coral species and that MTA can be superior competitors than *M. faveolata* under experimental conditions. *M. faveolata* is sensitive to algae and bacteria, and the outlook for this coral species is poor if deleterious conditions act together in the Caribbean Sea.

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Fong, P., Smith, T.B., and Wartian, M.J. **Epiphytic cyanobacteria maintain shifts to macroalgal dominance on coral reefs following ENSO disturbance.** *Ecology* 87(5): 1162-1168, 2006.

**Notes:** Macroalgal dominance of some tropical reef communities in the Eastern Pacific after coral mortality during the 1997-1998 El Nino Southern Oscillation (ENSO) was facilitated by protection from herbivory by epiphytic cyanobacteria. Our results do not support that reduction in number of herbivores was a necessary precursor to coral reef decline and shifts to algal reefs in this system. Rather, macroalgae dominated the community for several years after this pulse disturbance with no concurrent change in herbivore populations. While results of microcosm experiments identified the importance of nutrients, especially phosphorus, in stimulating macroalgal growth, nutrient supply alone could not sustain macroalgal dominance as nutrient-stimulated growth rates in our in situ experiments never exceeded consumption rates of unprotected thalli. In addition, thalli with nutrient-enriched tissue were preferentially consumed, possibly negating the positive effects of nutrients on growth. These tropical reefs may be ideal systems to conduct experimental tests distinguishing phase shifts from alternative stable states. Shifts were initiated by a large-scale disturbance with no evidence of a changing environment except, perhaps, dilution in herbivory pressure due to increased algal cover. Community establishment was most likely stochastic, and the community was likely maintained by strongly positive interaction between macroalgal hosts and cyanobacterial epiphytes that uncoupled consumer control of community structure.

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Yates, K.K. and Halley, R.B. **CO<sub>3</sub><sup>2-</sup> concentration and pCO<sub>2</sub> thresholds for calcification and dissolution on the Molokai reef flat, Hawaii.** *Biogeosciences* 3(3): 357-369, 2006.

**Notes:** The severity of the impact of elevated atmospheric pCO<sub>2</sub> to coral reef ecosystems depends, in part, on how seawater pCO<sub>2</sub> affects the balance between calcification and dissolution of carbonate sediments. Presently, there are insufficient published data that relate concentrations of pCO<sub>2</sub> and CO<sub>3</sub><sup>2-</sup> to in situ rates of reef calcification in natural settings to accurately predict the impact of elevated atmospheric pCO<sub>2</sub> on calcification and dissolution processes. Rates of net calcification and dissolution, CO<sub>3</sub><sup>2-</sup> concentrations, and pCO<sub>2</sub> were measured, in situ, on patch reefs, bare sand, and coral rubble on the Molokai reef flat in Hawaii. Rates of calcification ranged from 0.03 to 2.30 mmol CaCO<sub>3</sub> m<sup>-2</sup> h<sup>-1</sup> and dissolution ranged from -0.05 to -3.3 mmol CaCO<sub>3</sub> m<sup>-2</sup> h<sup>-1</sup>. Calcification and dissolution varied diurnally with net calcification primarily occurring during the day and net dissolution occurring at night. These data were used to calculate threshold values for pCO<sub>2</sub> and CO<sub>3</sub><sup>2-</sup> at which rates of calcification and dissolution are equivalent. Results indicate that calcification and dissolution are linearly correlated with both CO<sub>3</sub><sup>2-</sup> and pCO<sub>2</sub>. Threshold pCO<sub>2</sub> and CO<sub>3</sub><sup>2-</sup> values for individual substrate types showed considerable variation. The average pCO<sub>2</sub> threshold value for all substrate types was 654 +/- 195 μatm and ranged from 467 to 1003 μatm. The average CO<sub>3</sub><sup>2-</sup> threshold value was 152 +/- 24 μmol kg<sup>-1</sup>, ranging from 113 to 184 μmol kg<sup>-1</sup>. Ambient seawater measurements of pCO<sub>2</sub> and CO<sub>3</sub><sup>2-</sup> indicate that CO<sub>3</sub><sup>2-</sup> and pCO<sub>2</sub> threshold values for all substrate types were both exceeded, simultaneously, 13% of the time at present day atmospheric pCO<sub>2</sub> concentrations. It is predicted that atmospheric pCO<sub>2</sub> will exceed the average pCO<sub>2</sub> threshold value for calcification and dissolution on the Molokai reef flat by the year 2100.

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Bellwood, D.R., Hoey, A.S., Ackerman, J.L., and Depczynski, M. **Coral bleaching, reef fish community phase shifts and the resilience of coral reefs.** *Global Change Biology* 12(9): 1587-1594, 2006.

**Notes:** The 1998 global coral bleaching event was the largest recorded historical disturbance of coral reefs and resulted in extensive habitat loss. Annual censuses of reef fish community structure over a 12-year period spanning the bleaching event revealed a marked phase shift from a prebleach to postbleach assemblage. Surprisingly, we found that the bleaching event had no detectable effect on the abundance, diversity or species richness of a local cryptobenthic reef fish community. Furthermore, there is no evidence of regeneration even after 5-35 generations of these short-lived species. These results have significant implications for our understanding of the response of coral reef ecosystems to global warming and highlight the importance of selecting appropriate criteria for evaluating reef resilience.

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Fox, H.E. and Caldwell, R.L. **Recovery from blast fishing on coral reefs: A tale of two scales.** *Ecological Applications* 16(5): 1631-1635, 2006.

**Notes:** Dynamite or "blast" fishing is one of the most immediate and destructive threats to coral reefs worldwide. However, little is known about the long-term ecosystem effects of such blasts or the dynamics of recovery. Here, we examine coral reef recovery in the simplest case of acute single blasts of known age, as well as recovery from chronic blasting over greater spatial and temporal scales. Rubble resulting from single blasts slowly stabilized, and craters filled in with surrounding coral and new colonies. After five years, coral cover within craters no longer differed significantly from control plots. In contrast, extensively bombed areas showed no significant recovery over the six years of this study, despite adequate supply of coral larvae. After extensive blasting, the resulting coral rubble shifts in ocean currents, forming unstable "killing fields" for new recruits. While recently tested rehabilitation methods might be feasible on a small scale, human intervention is unlikely to be effective on large spatial scales, highlighting the need for effective management to prevent blast fishing in the first place.

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Van Oppen, M.J.H. and Gates, R.D. **Conservation genetics and the resilience of reef-building corals.** *Molecular Ecology* 15(13): 3863-3883, 2006.

**Notes:** Coral reefs have suffered long-term decline due to a range of anthropogenic disturbances and are now also under threat from climate change. For appropriate management of these vulnerable and valuable ecosystems it is important to understand the factors and processes that determine their resilience and that of the organisms inhabiting them, as well as those that have led to existing patterns of coral reef biodiversity. The scleractinian (stony) corals deposit the structural framework that supports and promotes the maintenance of biological diversity and complexity of coral reefs, and as such, are major components of these ecosystems. The success of reef-building corals is related to their obligate symbiotic association with dinoflagellates of the genus *Symbiodinium*. These one-celled algal symbionts (zooxanthellae) live in the endodermal tissues of their coral host, provide most of the host's energy budget and promote rapid calcification. Furthermore, zooxanthellae are the main primary producers on coral reefs due to the oligotrophic nature of the surrounding waters. In this review paper, we summarize and critically evaluate studies that have employed genetics and/or molecular biology in examining questions relating to the evolution and ecology of reef-building corals and their algal endosymbionts, and that bear relevance to coral reef conservation. We discuss how these studies can focus future efforts, and examine how these approaches enhance our understanding of the resilience of reef-building corals.

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Kunkel, C.M., Hallberg, R.W., and Oppenheimer, M. **Coral reefs reduce tsunami impact in model simulations.** *Geophysical Research Letters* 33(23): art. L23612, 2006.

**Notes:** Significant buffering of the impact of tsunamis by coral reefs is suggested by limited observations and some anecdotal reports, particularly following the 2004 Indian Ocean tsunami. Here we simulate tsunami run-up on idealized topographies in one and two dimensions using a nonlinear shallow water model and show that a sufficiently wide barrier reef within a meter or two of the surface reduces run-up on land on the order of 50%. We studied topographies representative of volcanic islands (islands with no continental shelf) but our conclusions may pertain to other topographies. Effectiveness depends on the amplitude and wavelength of the incident tsunami, as well as the geometry and health of the reef and the offshore distance of

the reef. Reducing the threat to reefs from anthropogenic nutrients, sedimentation, fishing practices, channel-building, and global warming would help to protect some islands against tsunamis.

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Pandolfi, J.M., Tudhope, A.W., Bur, G., Chappell, J., Edinger, E., Frey, M., Steneck, R., Sharma, C., Yeates, A., Jennions, M., Lescinsky, H., and Newton, A. **Mass mortality following disturbance in Holocene coral reefs from Papua New Guinea.** *Geology* 34(11): 949-952, 2006.

**Notes:** The frequency and intensity of disturbance on living coral reefs have been accelerating for the past few decades, resulting in a changed seascape. What is unclear but vital for management is whether this acceleration is natural or coincident only with recent human impact. We surveyed nine uplifted early to mid-Holocene (11,000-3700 calendar [cal] yr B.P.) fringing and barrier reefs along 27 km at the Huon Peninsula, Papua New Guinea. We found evidence for several episodes of coral mass mortality, but frequency was <1 in 1500 yr. The most striking mortality event extends >16 km along the ancient coastline, occurred ca. 9100-9400 cal yr B.P., and is associated with a volcanic ash horizon. Recolonization of the reef surface and resumption of vertical reef accretion was rapid (<100 yr), but the post-disturbance reef communities contrasted with their pre-disturbance counterparts. Assessing the frequency, nature, and long-term ecological consequences of mass-mortality events in fossil coral reefs may provide important insights to guide management of modern reefs in this time of environmental degradation and change.

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Newman, M.J.H., Paredes, G.A., Sala, E., and Jackson, J.B.C. **Structure of Caribbean coral reef communities across a large gradient of fish biomass.** *Ecology Letters* 9(11): 1216-1227, 2006.

**Notes:** The collapse of Caribbean coral reefs has been attributed in part to historic overfishing, but whether fish assemblages can recover and how such recovery might affect the benthic reef community has not been tested across appropriate scales. We surveyed the biomass of reef communities across a range in fish abundance from 14 to 593 g m<sup>-2</sup>, a gradient exceeding that of any previously reported for coral reefs. Increased fish biomass was correlated with an increased proportion of apex predators, which were abundant only inside large marine reserves. Increased herbivorous fish biomass was correlated with a decrease in fleshy algal biomass but corals have not yet recovered.

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Wilson, S.K., Graham, N.A.J., Pratchett, M.S., Jones, G.P., and Polunin, N.V.C. **Multiple disturbances and the global degradation of coral reefs: Are reef fishes at risk or resilient?** *Global Change Biology* 12(11): 2220-2234, 2006.

**Notes:** Increased frequency of disturbances and anthropogenic activities are predicted to have a devastating impact on coral reefs that will ultimately change the composition of reef associated fish communities. We reviewed and analysed studies that document the effects of disturbance-mediated coral loss on coral reef fishes. Meta-analysis of 17 independent studies revealed that 62% of fish species declined in abundance within 3 years of disturbances that resulted in > 10% decline in coral cover. Abundances of species reliant on live coral for food and shelter consistently declined during this time frame, while abundance of some species that feed on invertebrates, algae and/or detritus increased. The response of species, particularly those expected to benefit from the immediate loss of coral, is, however, variable and is attributed to erratic replenishment of stocks, ecological versatility of species and sublethal responses, such as changes in growth, body condition and feeding rates. The diversity of fish communities was found to be negatively and linearly correlated to disturbance-mediated coral loss. Coral loss > 20% typically resulted in a decline in species richness of fish communities, although diversity may initially increase following small declines in coral cover from high coverage. Disturbances that result in an immediate loss of habitat complexity (e.g. severe tropical storms), have a greater impact on fishes from all trophic levels, compared with disturbances that kill corals, but leave the reef framework intact (e.g. coral bleaching and outbreaks of *Acanthaster planci*). This is most evident among small bodied species and suggests the long-term consequences of coral loss through coral bleaching and crown-of-thorn starfish outbreaks may be much more substantial than the short-term effects currently documented.

Reshef, L., Koren, O., Loya, Y., Zilber-Rosenberg, I., and Rosenberg, E. **The Coral Probiotic Hypothesis.** *Environmental Microbiology* 8(12): 2068-2073, 2006.

**Notes:** Emerging diseases have been responsible for the death of about 30% of corals worldwide during the last 30 years. Coral biologists have predicted that by 2050 most of the world's coral reefs will be destroyed. This prediction is based on the assumption that corals can not adapt rapidly enough to environmental stress-related conditions and emerging diseases. Our recent studies of the *Vibrio shiloi* / *Oculina patagonica* model system of the coral bleaching disease indicate that corals can indeed adapt rapidly to changing environmental conditions by altering their population of symbiotic bacteria. These studies have led us to propose the Coral Probiotic Hypothesis. This hypothesis posits that a dynamic relationship exists between symbiotic microorganisms and environmental conditions which brings about the selection of the most advantageous coral holobiont. Changing their microbial partners would allow the corals to adapt to changing environmental conditions more rapidly (days to weeks) than via mutation and selection (many years). An important outcome of the Probiotic Hypothesis would be development of resistance of the coral holobiont to diseases. The following evidence supports this hypothesis: (i) Corals contain a large and diverse bacterial population associated with their mucus and tissues; (ii) the coral-associated bacterial population undergoes a rapid change when environmental conditions are altered; and (iii) although lacking an adaptive immune system (no antibodies), corals can develop resistance to pathogens. The Coral Probiotic Hypothesis may help explain the evolutionary success of corals and moderate the predictions of their demise.

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Downs, C.A., Richmond, R.H., Mendiola, W.J., Rougee, L., and Ostrander, G.K. **Cellular physiological effects of the MV Kyowa Violet fuel-oil spill on the hard coral, *Porites lobata*.** *Environmental Toxicology and Chemistry* 25(12): 3171-3180, 2006.

**Notes:** The grounding of the Merchant Vessel (MV) Kyowa Violet on a coral reef near Yap, Federated States of Micronesia, in December 2002 resulted in the release of an estimated 55,000 to 80,000 gallons of intermediate fuel oil grade 180. The immediate impact was the widespread coating of mangroves and the intertidal zone along more than 8 km of coastline. Of greater concern, however, was the partitioning of the fuel oil in the water column, leading to chronic exposure of organisms in the ecosystem for a considerable period after the initial event. Herein, we report on our examination of one coral species, *Porites lobata*, nearly three months after the initial exposure. We investigated whether changes in cellular physiology were consistent with the pathological profile that results from the interaction of corals with polycyclic aromatic hydrocarbons, the principal constituent of fuel oil. Specifically, we document, to our knowledge for the first time, changes in the cellular physiological condition of an exposed coral population affected by a fuel-oil spill. We also provide evidence that the observed changes are consistent with a recent exposure to fuel oil, as evidenced by the presence of characteristic cellular lesions attributed to polycyclic aromatic hydrocarbons. Finally, our data support a model for a mechanistic relationship between the cellular pathological profile of the coral and a recent petroleum exposure, such as the MV Kyowa Violet fuel oil spill.

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Rodolfo-Metalpa, R., Richard, C., Allemand, D., and Ferrier-Pages, C. **Growth and photosynthesis of two Mediterranean corals, *Cladocora caespitosa* and *Oculina patagonica*, under normal and elevated temperatures.** *Journal of Experimental Biology* 209(22): 4546-4556, 2006.

**Notes:** The Ligurian Sea (NW Mediterranean) experienced warm summers in 1998, 1999 and from 2003 to 2005. The temperature was 1-3°C higher than the mean summer value (24°C) and remained high over a long period. During these summers, mass-mortality events, affecting several sessile benthic species, were reported. In the present study, we tested the long-term (3-7 weeks) effect of different temperatures (20°C measured in spring and autumn, 24°C observed in summer, and 26°C and 28°C abnormal summer values) on two Mediterranean corals, *Cladocora caespitosa* and *Oculina patagonica*. Growth rate, photosynthetic efficiency ( $F_v/F_m$ ), relative electron transport rate (ETR), zooxanthellae and chlorophyll (chl) contents were measured during 48 days incubation. At 20°C, all parameters remained constant during the whole experiment for both species. At higher temperatures, most physiological parameters were affected by only 2-5 weeks at 24°C, and were severely depressed at higher temperatures. Small replicate samples (nubbins) of *O. patagonica* significantly decreased their zooxanthellae and chl concentrations at all temperatures, after 2 weeks of incubation. Their  $F_v/F_m$  values, as well as their growth rates, were also gradually reduced during the incubation at all temperatures. However, only a few nubbins maintained at 28°C showed signs of tissue necrosis after 34 days, and these gradually recovered tissue when temperature was returned to normal. In nubbins of *C. caespitosa*, chl and zooxanthellae concentrations decreased only after 34 days of incubation at 26°C and 28°C. At the same time, tissue necrosis was observed, explaining the loss of the symbionts.  $F_v/F_m$  was reduced only after 34 days of incubation at the different temperatures, and growth rate was first enhanced, before collapsing by 30% at 24°C and by 90-100% at 26°C and

28°C. All samples maintained at 26°C and 28°C had died, due to tissue necrosis, by the end of the experiment. Results obtained suggest that *O. patagonica* is more able than *C. caespitosa* to resist high temperature conditions because of its rapid bleaching capacity. In contrast, it seems that *C. caespitosa* is living close to its thermal limit during the summer period; therefore, a long-term increase at 24°C or above could be lethal for this coral, just as was observed in situ during the recent warm summers.

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Watanabe, T., Yuyama, I., and Yasumura, S. **Toxicological effects of biocides on symbiotic and aposymbiotic juveniles of the hermatypic coral *Acropora tenuis*.** *Journal of Experimental Marine Biology and Ecology* 339(2): 177-188, 2006.

**Notes:** Reef-building (or hermatypic) corals harbor the symbiotic dinoflagellates *Symbiodinium* spp. (Alveolata, Dinophyceae, Gymnodiniales), and contribute to the accretion of coral reefs in tropical and sub-tropical zones. In this study, toxicological effects of three commonly used biocides (dichlorvos (DDVP), a commonly used insecticide; diuron (DCMU), a herbicide; and tributyltin chloride (TBT-Cl), an anti-fouling agent) on the hermatypic coral *Acropora tenuis* (Anthozoa, Hexacorallia, Scleractinia) were studied using juveniles in both aposymbiotic (symbiont-free) and symbiotic conditions. After exposure to the chemicals, abnormalities such as detachment of soft tissues from the skeleton and/or death were observed, as well as lowered uptake of symbiotic algae (in aposymbiotic juveniles) or reduction of the symbiont population in tentacles (in symbiotic juveniles). Significant reduction of the symbiont population in tentacles of symbiotic juveniles exposed to DDVP, DCMU and TBT-Cl was observed at the concentrations of 100, 10, and 1 mg/l, respectively. Results of this study suggested that symbiotic juveniles of *A. tenuis* are more sensitive than in the aposymbiotic condition to DDVP and DCMU, but not to TBT-Cl.

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Pratchett, M.S., Wilson, S.K., and Baird, A.H. **Long-term monitoring of the Great Barrier Reef.** *Journal of Fish Biology* 69(5): 1269-1280, 2006.

**Notes:** This study documented temporal variation in the abundance of butterflyfishes (Chaetodontidae) at Trunk Reef, on the central Great Barrier Reef, Australia, from May 2000 to March 2005. During this period, live coral cover declined by > 90%, mostly due to severe coral bleaching. There were no short-term changes (within 4 months) in the abundance of butterflyfishes following initial declines in live coral cover. Surveys conducted in 2005, however, revealed significant declines in the abundance of *Chaetodon baronessa*, *Chaetodon lunulatus*, *Chaetodon trifascialis*, *Chaetodon plebeius* and *Chaetodon rainfordi*, all of which are obligate hard-coral feeders. In contrast, there was no significant change in the abundance of *Chaetodon auriga*, *Chaetodon aureofasciatus*, *Chaetodon citrinellus*, *Chaetodon melannotus* or *Chaetodon vagabundus*, which are much less reliant on scleractinian coral for food. Clearly, extensive coral depletion, such as that caused by severe coral bleaching, can have a major effect on the abundance of butterflyfishes. Specific responses of butterflyfishes varied according to their reliance on hard corals for food and their ability to utilize alternate prey types.

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Subade, R.F. **Mechanisms to capture economic values of marine biodiversity: The case of Tubbataha Reefs UNESCO World Heritage Site, Philippines.** *Marine Policy* 31(2): 135-142, 2007.

**Notes:** This paper examines the use and non-use values of coral reefs as applied to the Tubbataha Reefs UNESCO World Heritage Site. Results from various studies indicate that economic benefits/values from conservation far exceed the costs of conservation. Mechanisms on how such economic values have been and can be captured are discussed. It is noted that non-use values could provide huge capturable economic values.

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Nordemar, I., Sjøo, G.L., Mork, E., and McClanahan, T.R. **Effects of estimated herbivory on the reproductive potential of four East African algal species - a mechanism behind ecosystem shifts on coral reefs?** *Hydrobiologia* 575: 57-68, 2007.

**Notes:** The aim of this field study was to investigate effects of estimated fish and sea urchin herbivory on the reproductive potential of four species of macroalgae; *Halimeda macroloba* (Decasine), *H. renschii* (Hauck), *Turbinaria ornata* (Turner) and *Padina*

*boergesenii* (Allender et Kraft). Fish and sea urchin herbivory were calculated based on reported consumption rates for their biomass estimates. We hypothesized that reduced herbivory would increase algal size and the reproductive potential, which may promote algal recruitment and be one of the driving mechanisms behind algal shifts and persistent algae-dominated reefs. Algae were investigated in field sites where the estimated fish- and or sea urchin herbivory differed. Our results suggest that algal fecundity of *T. ornata* and *P. boergesenii* are positively correlated to their size. Fecundity of *T. ornata* was higher and individuals grew larger in areas where estimated fish herbivory was lower. The two species of *Halimeda* grew larger and had higher fecundity in areas where estimated sea urchin herbivory was lower. *P. boergesenii* responded ambiguously to patterns in herbivory. Due to species-specific responses to different herbivores, it is difficult to generalize about effects of overfishing on algal fecundity.

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Willis, B.L., Van Oppen, M.J.H., Miller, D.J., Vollmer, S.V., and Ayre, D.J. **The role of hybridization in the evolution of reef corals.** *Annual Review of Ecology, Evolution, and Systematics* 37: 489-517, 2006.

**Notes:** The importance of hybridization in the evolution of plant species is widely accepted, but its contributions to animal species evolution remain less recognized. Here we review evidence that hybridization has contributed to the evolution of reef corals, a group underpinning the coral reef ecosystem. Increasingly threatened by human and climate-related impacts, there is need to understand the evolutionary processes that have given rise to their diversity and contribute to their resilience. Reticulate evolutionary pathways among the ecologically prominent, mass-spawning genus *Acropora* suggest that hybridization, although rare on ecological timescales, has been instrumental in their diversification on evolutionary timescales. Evidence that coral hybrids colonize marginal habitats distinct from those of parental species' and that hybridization may be more frequent at peripheral boundaries of species' ranges supports a role for hybridization in range expansion and adaptation to changing environments. We conclude that outcomes of hybridization are significant for the future resilience of reef corals and warrant inclusion in conservation strategies.

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Lambo, A.L. and Ormond, R.F.G. **Continued post-bleaching decline and changed benthic community of a Kenyan coral reef.** *Marine Pollution Bulletin* 52(12): 1617-1624, 2006.

**Notes:** During the global coral bleaching event of 1997/1998 Kenyan reefs experienced between 50% and 90% coral mortality, with coral cover at Malindi being reduced from 35-45% (pre-bleaching) to 10-20%. Even before this event there was concern that these reefs were being impacted by increased sediment loads from the nearby Sabaki River. Here we report that since 1998 coral cover has declined yet further with, in 2004, means of 5.1% being recorded at North Reef (within the non-fished Malindi Marine National Park) and 2.3% on Leopard Reef (within the fished Marine Reserve). Prior to bleaching 55 coral genera were recorded from the area, currently we find only 23. Meanwhile algal cover, especially the calcareous green alga *Halimeda*, has increased, and on Leopard Reef is twice that on North Reef. Taken with the evidence of previous studies, these data suggest a combined impact of coral bleaching with sedimentation and fishing.

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Bellwood, D.R., Hughes, T.P., and Hoey, A.S. **Sleeping functional group drives coral-reef recovery.** *Current Biology* 16(24): 2434-2439, 2006.

**Notes:** The world's coral reefs are in decline, with many exhibiting a phase shift from coral to macroalgal dominance. This change is often associated with habitat loss and overharvesting of herbivorous fishes, particularly parrotfishes and surgeonfishes. The challenge is to reverse this decline and enhance the resilience of coral-reef ecosystems. We demonstrate, by using a large-scale experimentally induced phase shift, that the rapid reversal from a macroalgal-dominated to a coral- and epilithic algal-dominated state was not a result of herbivory by parrotfishes or surgeonfishes. Surprisingly, phase-shift reversal was primarily driven by a single batfish species (*Platax pinnatus*), a fish previously regarded as an invertebrate feeder. The 43 herbivorous fishes in the local fauna played only a minor role, suggesting that biodiversity may not offer the protection we hoped for in complex ecosystems. Our findings highlight the dangers faced by coral reefs and other threatened complex ecosystems: Species or functional groups that prevent phase shifts may not be able to reverse phase shifts once they occur. Nevertheless, reversal is possible. The critical issue is to identify and protect those groups that underpin the resilience and regeneration of complex ecosystems.

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Hughes, T.P., Rodrigues, M.J., Bellwood, D.R., Ceccarelli, D., Hoegh-Guldberg, O., McCook, L., Moltschaniwskyj, M., Pratchett, M.S., Steneck, R.S., and Willis, B. **Phase shifts, herbivory, and the resilience of coral reefs to climate change.** *Current Biology* 17(4): 360-365, 2007.

**Notes:** Many coral reefs worldwide have undergone phase shifts to alternate, degraded assemblages because of the combined effects of overfishing, declining water quality, and the direct and indirect impacts of climate change. Here, we experimentally manipulated the density of large herbivorous fishes to test their influence on the resilience of coral assemblages in the aftermath of regional-scale bleaching in 1998, the largest coral mortality event recorded to date. The experiment was undertaken on the Great Barrier Reef, within a no-fishing reserve where coral abundances and diversity had been sharply reduced by bleaching. In control areas, where fishes were abundant, algal abundance remained low, whereas coral cover almost doubled (to 20%) over a 3 year period, primarily because of recruitment of species that had been locally extirpated by bleaching. In contrast, exclusion of large herbivorous fishes caused a dramatic explosion of macroalgae, which suppressed the fecundity, recruitment, and survival of corals. Consequently, management of fish stocks is a key component in preventing phase shifts and managing reef resilience. Importantly, local stewardship of fishing effort is a tractable goal for conservation of reefs, and this local action can also provide some insurance against larger-scale disturbances such as mass bleaching, which are impractical to manage directly.

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Rotjan, R.D., Dimond, J.L., Thornhill, D.J., Leichter, J.J., Helmuth, B., Kemp, D.W., and Lewis, S.M. **Chronic parrotfish grazing impedes coral recovery after bleaching.** *Coral Reefs* 25(3): 361-368, 2006.

**Notes:** Coral bleaching, in which corals become visibly pale and typically lose their endosymbiotic zooxanthellae (*Symbiodinium* spp.), increasingly threatens coral reefs worldwide. While the proximal environmental triggers of bleaching are reasonably well understood, considerably less is known concerning physiological and ecological factors that might exacerbate coral bleaching or delay recovery. We report a bleaching event in Belize during September 2004 in which *Montastraea* spp. corals that had been previously grazed by corallivorous parrotfishes showed a persistent reduction in symbiont density compared to intact colonies. Additionally, grazed corals exhibited greater diversity in the genetic composition of their symbiont communities, changing from uniform ITS2 type C7 *Symbiodinium* prior to bleaching to mixed assemblages of *Symbiodinium* types post-bleaching. These results suggest that chronic predation may exacerbate the influence of environmental stressors and, by altering the coral-zooxanthellae symbiosis, such abiotic-biotic interactions may contribute to spatial variation in bleaching processes.

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Wulff, J.L. **A simple model of growth form-dependent recovery from disease in coral reef sponges, and implications for monitoring.** *Coral Reefs* 25(3): 419-426, 2006.

**Notes:** For clonal organisms that can suffer high levels of partial mortality and still recover, the conditions that influence infection and development of disease (e.g., abiotic stressors, population density) may be very different from the conditions that influence recovery. Recovery from infectious disease may increase if an individual can mount a defense before infection spreads throughout its body. If pathogens spread within an organism from an initial infection point, growth form - in conjunction with size - can influence the amount of time before all the tissue is diseased, and recovery precluded. A simple model of pathogen progression within individual sponges predicts that species with massive growth forms will be most susceptible to being overwhelmed by pathogen infection, and branching species will be most likely to recover. These predictions may help to explain the seemingly contradictory observations that branching species had the greatest prevalence of disease, and massive species the greatest rate of loss, in a monitored coral reef community. Disease may be observed disproportionately frequently in the organisms that are most likely to recover, resulting in underestimation, by standard monitoring procedures, of the effect of disease on losses from the community.

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Aronson, R.B. and Precht, W.F. **Conservation, precaution, and Caribbean reefs.** *Coral Reefs* 25(3): 441-450, 2006.

**Notes:** Some authors argue that overfishing is an important reason that reef corals have declined in recent decades. Their reasoning is that overfishing removes herbivores, releasing macroalgae to overgrow and kill the corals. The evidence suggests,

however, that global climate change and emergent marine diseases make a far greater contribution to coral mortality, and that macroalgae generally grow on the exposed skeletal surfaces of corals that are already dead. Macroalgal dominance, therefore, is an effect rather than a cause of coral mortality. Marine protected areas (MPAs), which are usually established to protect stocks of reef fish, foster populations of herbivorous fish under at least some circumstances. Increased herbivory can reduce algal cover, potentially accelerating the recovery of coral populations inside MPAs; however, establishing MPAs will have only a limited impact on coral recovery unless policymakers confront the accelerating negative effects of the global-scale sources of coral mortality.

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Berumen, M.L. and Pratchett, M.S. **Recovery without resilience: persistent disturbance and long-term shifts in the structure of fish and coral communities at Tiahura Reef, Moorea.** *Coral Reefs* 25(4): 647-653, 2006.

**Notes:** Disturbances have a critical effect on the structure of natural communities. In this study long-term changes were examined in the reef community at Tiahura Reef, on the northern coast of Moorea, which had been subject to many and varied disturbances over the last 25 years. Tiahura Reef was subject to an outbreak of crown-of-thorns starfish (*Acanthaster planci*) in 1980-1981, causing significant declines in the abundance of scleractinian corals and butterflyfishes. By 2003, the abundance of corals and butterflyfishes had returned to former levels, but despite this apparent recovery, the species composition of coral communities and butterflyfish assemblages was very different from those recorded in 1979. Ongoing disturbances (including further outbreaks of crown-of-thorns starfish, cyclones, and coral bleaching events) appear to have prevented recovery of many important coral species (notably, *Acropora* spp.), which has had subsequent effects on the community structure of coral-feeding butterflyfishes. This study shows that recurrent disturbances may have persistent effects on the structure and dynamics of natural communities.

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Goulet, T.L. **Most corals may not change their symbionts.** *Marine Ecology Progress Series* 321: 1-7, 2006.

**Notes:** Many corals (stony corals and octocorals) rely on their symbiotic algae (zooxanthellae) for survival. Under stress, zooxanthellae are expelled, resulting in coral bleaching. The hypothesis that corals may survive climate change by exchanging algal types is shown here to be potentially applicable only to a minority of corals. Data on 442 coral species from 43 studies reveal that only a few coral species may be able to change their symbionts. The ability to change symbionts seems to be linked to whether a coral species can host multiple zooxanthella clades, either at different depths on the same reef, on different reefs or at different geographic locations, or concurrently within the same colony. The combined data set shows that only 23% of coral species host multiple zooxanthella clades. Most coral species (77%) exhibit fidelity to a narrow subset of a single zooxanthella clade, some even to specific algal genotypes within a clade. These specific algal genotypes in coral species hosting a single algal clade do not change over time. Furthermore, no algal change occurs when a coral colony is either transplanted to different environments, or subjected to stressors such as disease or increased temperatures. For the majority of corals, therefore, algal switching does not appear to occur. These coral species will survive only if the existing host-symbiont combination withstands the changing conditions. If climate warming continues, coral reefs may undergo a change in biodiversity such that only a subset of symbiotic corals may persist.

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Grober-Dunsmore, R., Bonito, V., and Frazer, T.K. **Potential inhibitors to recovery of *Acropora palmata* populations in St. John, US Virgin Islands.** *Marine Ecology Progress Series* 321: 123-132, 2006.

**Notes:** Populations of *Acropora palmata* in the Caribbean were decimated in the 1970s and 1980s, with little apparent signs of recovery until the late 1990s. Here, we document an increase in *A. palmata* colonies between 2001 and 2003 at 8 of 11 monitoring sites in waters adjacent to the island of St. John, US Virgin Islands. The shallow waters along the NW coast of the island exhibited the greatest increase in colony abundance, perhaps due to greater larval supply and/or conditions that favor settlement and subsequent survivorship. Of concern, however, is the lack of survival of large colonies (at all sites), which are most frequently affected by stressors (e.g. *Coralliophila abbreviata*, damselfishes, active disease) and are most likely to be remnants (colonies with discontinuous, living coral-tissue over an existing coral framework). Predation by *C. abbreviata* and active coral disease may directly contribute to the development of these remnant colonies. In addition, we recorded damage to colonies attributed to damselfishes and raise the possibility that these territorial reef-inhabitants act as vectors in the transmission of coral disease. While the incidence of disease around St. John is generally low, it may persist as a ubiquitous,

chronic stress. Finally, because stressors are more prevalent on large colonies and in high-density stands, they have the potential to inhibit the recovery of *A. palmata* populations to their historic condition.

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Ritchie, K.B. **Regulation of microbial populations by coral surface mucus and mucus-associated bacteria.** *Marine Ecology Progress Series* 322: 1-14, 2006.

**Notes:** Caribbean populations of the elkhorn coral *Acropora palmata* have declined due to environmental stress, bleaching, and disease. Potential sources of coral mortality include invasive microbes that become trapped in the surface mucus and thrive under conditions of increased coral stress. In this study, mucus from healthy *A. palmata* inhibited growth of potentially invasive microbes by up to 10-fold. Among cultured bacteria from the mucus of *A. palmata*, 20% displayed antibiotic activity against one or more tester strains, including the pathogen implicated in white pox disease. A novel mucus-mediated selection for coral symbionts revealed a discrete subset of bacteria and selected for isolates that produce antibiotics. This result suggests that coral mucus plays a role in the structuring of beneficial coral-associated microbial communities and implies a microbial contribution to the antibacterial activity described for coral mucus. Interestingly, antibiotic activity was lost when mucus was collected during a summer bleaching event. Isolates from apparently healthy *A. palmata* tissue during this event lacked antibiotic-producing bacteria and were dominated by members of the genus *Vibrio*, including species implicated in temperature-dependent bleaching of corals worldwide. This indicates an environmental shift from beneficial bacteria, and variability in the protective qualities of coral mucus, which may lead to an overgrowth of opportunistic microbes when temperatures increase. Finally, coral mucus inhibited antibiotic activity and pigment production in a potentially invasive bacterium, illustrating that coral mucus may inactivate mechanisms used for bacterial niche establishment.

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Kuffner, I.B., Walters, L.J., Becerro, M.A., Paul, V.J., Ritson-Williams, R., and Beach, K.S. **Inhibition of coral recruitment by macroalgae and cyanobacteria.** *Marine Ecology Progress Series* 323: 107-117, 2006.

**Notes:** Coral recruitment, is a key process in the maintenance and recovery of coral reef ecosystems. While intense competition between coral and algae is often assumed on reefs that have undergone phase shifts from coral to algal dominance, data examining the competitive interactions involved, particularly during the larval and immediate post-settlement stage, are scarce. Using a series of field and outdoor seawater table experiments, we tested the hypothesis that common species of macroalgae and cyanobacteria inhibit coral recruitment. We examined the effects of *Lynghya* spp., *Dictyota* spp., *Lobophora variegata* (J. V. Lamouroux) Womersley, and *Chondrophycus poiteau* (J. V. Lamouroux) Nam (formerly *Laurencia poiteau*) on the recruitment success of *Porites astreoides* larvae. All species but *C. poiteau* caused either recruitment inhibition or avoidance behavior in *P. astreoides* larvae, while *L. confervoides* and *D. menstrualis* significantly increased mortality rates of *P. astreoides* recruits. We also tested the effect of some of these macrophytes on larvae of the gorgonian octocoral *Briareum asbestinum*. Exposure to *Lynghya majuscula* reduced survival and recruitment in the octocoral larvae. Our results provide evidence that algae and cyanobacteria use tactics beyond space occupation to inhibit coral recruitment. On reefs experiencing phase shifts or temporary algal blooms, the restocking of adult coral populations may be slowed due to recruitment inhibition, thereby perpetuating reduced coral cover and limiting coral community recovery.

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