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# Marine Science Review – 382

## Coral and coral reefs

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In this review:



O/A denotes an open access article or journal

## A. Recent articles – no abstract

Sommer, B., Harrison, P.L., and Scheffers, S.R. **Aggressive colonial ascidian impacting deep coral reefs at Bonaire, Netherlands Antilles.** *Coral Reefs* 29(1): 245, 2010.

Foley, N.S., van Rensburg, T.M., and Armstrong, C.W. **The ecological and economic value of cold-water coral ecosystems.** *Ocean and Coastal Management* 53(7): 313-326, 2010.

## B. Recent publications available online

Bussoletti, E., D. Cottingham, A. Bruckner, G. Roberts, and R. Sandulli (editors). 2010. ***Proceedings of the International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean.*** NOAA Technical Memorandum CRCP 13, Silver Spring, MD. 233pp.

**Available at:** http://coris.noaa.gov/activities/lessons_mediterranean/

**Notes:** The family Coralliidae, consisting of the genera *Corallium* and *Paracorallium*, commonly known as red and pink corals, contains the most valuable and rarest taxa of precious corals in commerce. Seven species in this family have been intensively fished for use in jewelry, amulets, art objects, and homeopathic medicines. There is a well-established pattern of discovery, exploitation, and rapid depletion of stocks, with fisheries moving on to new beds as old ones are depleted. The International Workshop on Red Coral Science, Management, and Trade: Lessons from the Mediterranean was convened September 23-26, 2009 in Naples, Italy. Hosted by the Italian Ministry of Agriculture and Ministry of Environment and NOAA's Coral Reef Conservation Program, the workshop provided an opportunity to discuss the best available science on the natural history of Mediterranean red coral (*Corallium rubrum* L.) as well as how it is managed throughout the region and utilized around the world. Attendees included scientists, managers, representatives of the coral fishery, manufacturing industries, policy makers, and environmental organizations from Europe, Africa, Asia, and North America. The workshop involved presentations on the biology, taxonomy, and status of populations, fisheries, existing management approaches, trade and other and threats, uses of *Corallium*, and major markets. This information, plus the working group tasks and reports, are included in this report.

# C. Recent articles with abstracts

Rodolfo-Metalpa, R., Martin, S., Ferrier-Pages, C., and Gattuso, J. P. **Response of the temperate coral *Cladocora caespitosa* to mid- and long-term exposure to $pCO_2$ and temperature levels projected for the year 2100 AD.** *Biogeosciences* 7(1): 289-300, 2010. O/A

**Notes**: Atmospheric $CO_2$ partial pressure ($pCO_2$) is expected to increase to 700 µatm or more by the end of the present century. Anthropogenic $CO_2$ is absorbed by the oceans, leading to decreases in pH and the $CaCO_3$ saturation state (Ω) of the seawater. Elevated $pCO_2$ was shown to drastically decrease calcification rates in tropical zooxanthellate corals. Here we show, using the Mediterranean zooxanthellate coral *Cladocora caespitosa*, that an increase in $pCO_2$, in the range predicted for 2100, does not reduce its calcification rate. Therefore, the conventional belief that calcification rates will be affected by ocean acidification may not be widespread in temperate corals. Seasonal change in temperature is the predominant factor controlling photosynthesis, respiration, calcification and symbiont density. An increase in $pCO_2$, alone or in combination with elevated temperature, had no significant effect on photosynthesis, photosynthetic efficiency and calcification. The lack of sensitivity *C. caespitosa* to elevated $pCO_2$ might be due to its slow growth rates, which seem to be more dependent on temperature than on the saturation state of calcium carbonate in the range projected for the end of the century.

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Ledoux, J.B., Mokhtar-Jamai, K., Roby, C., Feral, J.P., Garrabou, J., and Aurelle, D. **Genetic survey of shallow populations of the Mediterranean red coral [*Corallium rubrum* (Linnaeus, 1758)]: new insights into evolutionary processes shaping nuclear diversity and implications for conservation.** *Molecular Ecology* 19(4): 675-690, 2010.

**Notes**: Combined action from over-harvesting and recent mass mortality events potentially linked to ongoing climate changes has led to new concerns for the conservation of shallow populations (5-60 m) of *Corallium rubrum*, an octocorallian that is mainly found in the Mediterranean Sea. The present study was designed to analyse population structure and relationships at different spatial scales (from 10s of meters to 100s of kilometres) with a focus on dispersal pattern. We also performed the first analysis of the distribution of genetic diversity using a comparative approach between regional-clusters and samples. Forty populations dwelling in four distinct regions between 14 and 60 m in depth were genotyped using 10 microsatellites. Our main results indicate (i) a generalized pair-sample differentiation combined with a weak structure between regional-clusters; (ii) the occurrence of isolation by distance at the global scale, but also within two of the three analysed regional-clusters; (iii) a high level of genetic diversity over the surveyed area with a heterogeneous distribution from regional-cluster to sample levels. The evolutionary consequences of these results are discussed and their management implications are provided.

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Mendonça, V.M., Al Jabri, M.M., Al Ajmi, I., Al Muharrami, M., Al Areimi, M., and Al Aghbari, H.A. **Persistent and expanding population outbreaks of the corallivorous starfish *Acanthaster planci* in the Northwestern Indian Ocean: Are they really a consequence of unsustainable starfish predator removal through overfishing in coral reefs, or a response to a changing environment?** *Zoological Studies* 49(1): 108-123, 2010. O/A

**Notes**: Population outbreaks of the starfish *Acanthaster planci* have been persisting for at least the past 25 yr on coral reefs in the Gulf of Oman, in the northwestern Indian Ocean. A survey conducted in 2001 showed that the *A. planci* population on the Dimaniyat Is. was as abundant (around 5 individuals (ind)/transect, equivalent to 100 ind/ha) as that recorded during an outbreak in the early 1980s. Local authorities are controlling starfish populations by culling relatively large adult individuals. These outbreaks cause considerable damage to coral communities, as observed specimens were adult individuals of about 60 cm in total diameter (no juveniles were observed). The situation has persisted for over 2 decades, and has now spread to coral reefs in the Arabian Gulf. Although *A. planci* population outbreaks were associated in the past with overfishing of starfish predators in coral reef areas, in the present study, we found no connection between this theory and starfish outbreaks, as stomach contents of carnivorous fish specimens likely to prey on this starfish species, caught on coral reefs on the Gulf of Oman, and sold at local fish markets (in Barka, Muscat, and Sur), showed no presence of *A. planci* in their diets. Therefore, the reason for *A. planci* population outbreaks could not have been due to overfishing of predator species, but is most likely to have been caused by the frequent input of nutrients, due to frequent upwelling events in the northwestern Indian Ocean, leading to planktonic blooms which thus enhance *A. planci* recruitment.

Rodgers, K.S., Jokiel, P.L., Bird, C.E., and Brown, E.K. **Quantifying the condition of Hawaiian coral reefs.** *Aquatic Conservation: Marine and Freshwater Ecosystems* 20(1): 93-105, 2010. **O/A**

**Notes**: (1) This investigation developed and tested descriptive models designed to evaluate coral reef ecological condition based on data developed using the basic techniques most often used in coral reef surveys. (2) Forty-three variables at 184 stations were analysed in order to identify specific factors that are useful metrics for describing reef condition. (3) The common practice of using 'reference sites' for paired site comparisons was evaluated by developing a reference site model (RSM). This use of reference sites proved to be subjective and unreliable, especially when multiple factors and multiple sites are involved. However, in some cases the RSM is appropriate in demonstrating severe degradation based on factors such as sediment, coral cover and fish abundance. (4) An objective ecological gradient model (EGM) was developed based on a wide range of metrics at numerous sites. A computer program was developed that allows a quantitative ranking of reef condition along a continuum and can be used to compare reefs across a wide range of conditions. Further, this approach permits the operator to alter and define criteria appropriate to a specific question. (5) Results of this investigation provide ecological insights into the importance of natural and anthropogenic ecological factors in determining coral reef condition.

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Hobbs, J.P.A. and Frisch, A.J. **Coral disease in the Indian Ocean: taxonomic susceptibility, spatial distribution and the role of host density on the prevalence of white syndrome.** *Diseases of Aquatic Organisms* 89(1): 1-8, 2010.

**Notes**: Coral diseases, such as white diseases and white syndrome (WS), have caused widespread damage to coral reefs throughout the Caribbean and are increasing in prevalence on Pacific Ocean reefs. The current study confirms that WS is also present on coral reefs in the Indian Ocean and tests whether patterns in taxonomic susceptibility and spatial variability conform to patterns of WS reported in the Pacific Ocean. Underwater surveys at 19 sites around Christmas and Cocos Islands revealed that WS primarily affects *Acropora* plate corals (*A. clathrata*, *A. cytherea* and *A. hyacinthus*), and prevalence of WS varied significantly across all 3 spatial scales investigated (island, exposure and depth). Approximately 13.0% (range = 0 to 43% per site) of plate corals at Christmas Island sites exhibited WS compared to <1% at the Cocos Islands. At Christmas Island, WS prevalence was greater in shallow (31.5%) than in deeper water (6.7%) and greatest on the northern (leeward) side of the island (31.5%) compared to the more exposed coastlines (0 to 1.5%). Importantly, the spatial distribution of WS was positively correlated with host density, but not with hard coral cover, suggesting a role of host density in WS outbreaks. Overall the present study has established that WS is impacting remote, near-pristine reefs in the Indian Ocean. However, the highly variable spatial distribution of WS illustrates that patterns in disease prevalence, and the subsequent impact on coral reefs, can be location- or region-specific.

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Rasher, D.B. and Hay, M.E. **Chemically rich seaweeds poison corals when not controlled by herbivores.** *Proceedings of the National Academy of Sciences [USA]* 107(21): 9683-9888, 2010. **O/A**

**Notes**: Coral reefs are in dramatic global decline, with seaweeds commonly replacing corals. It is unclear, however, whether seaweeds harm corals directly or colonize opportunistically following their decline and then suppress coral recruitment. In the Caribbean and tropical Pacific, we show that, when protected from herbivores, ~40 to 70% of common seaweeds cause bleaching and death of coral tissue when in direct contact. For seaweeds that harmed coral tissues, their lipid-soluble extracts also produced rapid bleaching. Coral bleaching and mortality was limited to areas of direct contact with seaweeds or their extracts. These patterns suggest that allelopathic seaweed-coral interactions can be important on reefs lacking herbivore control of seaweeds, and that these interactions involve lipid-soluble metabolites transferred via direct contact. Seaweeds were rapidly consumed when placed on a Pacific reef protected from fishing but were left intact or consumed at slower rates on an adjacent fished reef, indicating that herbivory will suppress seaweeds and lower frequency of allelopathic damage to corals if reefs retain intact food webs. With continued removal of herbivores from coral reefs, seaweeds are becoming more common. This occurrence will lead to increasing frequency of seaweed-coral contacts, increasing allelopathic suppression of remaining corals, and continuing decline of reef corals.

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Darling, E.S., McClanahan, T.R., and Côté, I.M. **Combined effects of two stressors on Kenyan coral reefs are additive or antagonistic, not synergistic.** *Conservation Letters* 3(2): 122-130, 2010. **O/A**

**Notes**: A challenge for conservation science is predicting the impacts of co-occurring human activities on ecological systems. Multiple anthropogenic and natural stressors impact ecosystems globally and are expected to jeopardize their ecological functions and the success of conservation and management initiatives. The possibility that two or more stressors interact synergistically is of particular concern, but such nonadditive effects remain largely unidentified in nature. A long-term data set of hard coral cover from Kenyan reefs was used to examine the independent and interactive effects of two stressors: fishing and a temperature anomaly in 1998 that caused mass coral bleaching and mortality. While both stressors decreased coral cover, fishing by 51% and bleaching by 74%, they did not interact synergistically. Instead, their combined effect was antagonistic or weakly additive. The observed nonsynergistic response may be caused by the presence of one dominant stressor, bleaching, and cotolerance of coral taxa to both bleaching and fishing stressors. Consequently, coral bleaching has been the dominant driver of coral loss on Kenyan reefs and while marine reserves offer many benefits to reef ecosystems, they may not provide corals with a refuge from climate change.

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Krief, S., Hendy, E.J., Fine, M., Yam, R., Meibom, A., Foster, G.L., and Shemesh, A. **Physiological and isotopic responses of scleractinian corals to ocean acidification.** *Geochimica et Cosmochimica Acta* 74(17): 4988-5001, 2010.

**Notes**: Uptake of anthropogenic $CO_2$ by the oceans is altering seawater chemistry with potentially serious consequences for coral reef ecosystems due to the reduction of seawater pH and aragonite saturation state ($\Omega_{arag}$). The objectives of this long-term study were to investigate the viability of two ecologically important reef-building coral species, massive *Porites* sp. and *Stylophora pistillata*, exposed to high $pCO_2$ (or low pH) conditions and to observe possible changes in physiologically related parameters as well as skeletal isotopic composition. Fragments of *Porites* sp. and *S. pistillata* were kept for 6-14 months under controlled aquarium conditions characterized by normal and elevated $pCO_2$ conditions, corresponding to $pH_T$ values of 8.09, 7.49, and 7.19, respectively. In contrast with shorter, and therefore more transient experiments, the long experimental timescale achieved in this study ensures complete equilibration and steady state with the experimental environment and guarantees that the data provide insights into viable and stably growing corals. During the experiments, all coral fragments survived and added new skeleton, even at seawater $\Omega_{arag} < 1$, implying that the coral skeleton is formed by mechanisms under strong biological control. Measurements of boron (B), carbon (C), and oxygen (O) isotopic composition of skeleton, C isotopic composition of coral tissue and symbiont zooxanthellae, along with physiological data (such as skeletal growth, tissue biomass, zooxanthellae cell density, and chlorophyll concentration) allow for a direct comparison with corals living under normal conditions and sampled simultaneously. Skeletal growth and zooxanthellae density were found to decrease, whereas coral tissue biomass (measured as protein concentration) and zooxanthellae chlorophyll concentrations increased under high $pCO_2$ (low pH) conditions. Both species showed similar trends of $\delta^{11}B$ depletion and $\delta^{18}O$ enrichment under reduced pH, whereas the $\delta^{13}C$ results imply species-specific metabolic response to high $pCO_2$ conditions. The skeletal $\delta^{11}B$ values plot above seawater $\delta^{11}B$ vs. pH borate fractionation curves calculated using either the theoretically derived $a_B$ value of 1.0194 (Kakihana *et al.* (1977) *Bull. Chem. Soc. Jpn.* **50**, 158) or the empirical $a_B$ value of 1.0272 (Klochko *et al.* (2006) *EPSL* **248**, 261). However, the effective $a_B$ must be greater than 1.0200 in order to yield calculated coral skeletal $\delta^{11}B$ values for pH conditions where $\Omega_{arag} \geq 1$. The $\delta^{11}B$ vs. pH offset from the seawater $\delta^{11}B$ vs. pH fractionation curves suggests a change in the ratio of skeletal material laid down during dark and light calcification and/or an internal pH regulation, presumably controlled by ion-transport enzymes. Finally, seawater pH significantly influences skeletal $\delta^{13}C$ and $\delta^{18}O$. This must be taken into consideration when reconstructing paleo-environmental conditions from coral skeletons.

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Shaw, M., Furnas, M.J., Fabricius, K., Haynes, D., Carter, S., Eaglesham, G., and Mueller, J.F. **Monitoring pesticides in the Great Barrier Reef.** *Marine Pollution Bulletin* 60(1): 113-122, 2010. **O/A**

**Notes**: Pesticide runoff from agriculture poses a threat to water quality in the world heritage listed Great Barrier Reef (GBR) and sensitive monitoring tools are needed to detect these pollutants. This study investigated the utility of passive samplers in this role through deployment during a wet and dry season at river mouths, two near-shore regions and an offshore region. The nearshore marine environment was shown to be contaminated with pesticides in both the dry and wet seasons (average water concentrations of 1.3 - 3.8 ng $L^{-1}$ and 2.2 - 6.4 ng $L^{-1}$, respectively), while no pesticides were detected further offshore. Continuous monitoring of two rivers over 13 months showed waters flowing to the GBR were contaminated with herbicides

(diuron, atrazine, hexazinone) year round, with highest average concentrations present during summer (350 ng $L^{-1}$). The use of passive samplers has enabled identification of insecticides in GBR waters which have not been reported in the literature previously.

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Jordan, L.K.B., Banks, K.W., Fisher, L.E., Walker, B.K., and Gilliam, D.S. **Elevated sedimentation on coral reefs adjacent to a beach nourishment project.** *Marine Pollution Bulletin* 60(2): 261-271, 2010.

**Notes**: An increasingly common method to restore eroding beaches is nourishment, a process by which lost sand is replaced with terrestrial or offshore sediments to widen beaches. The southeastern Florida coastline contains shore-parallel coral reef communities adjacent to eroding beaches. Scleractinian corals and other reef-associated organisms are known to demonstrate sensitivity to elevated sedimentation levels. Sediment traps were used to examine spatio-temporal sedimentation patterns and assess the effects of nourishment (dredge and fill) activities. Several environmental variables correlated with among-site spatial variability of sediment parameters. Intra-annual variability correlated with wind velocity and direction. Nourishment activities showed localized effects, with sites in close proximity to dredging areas exhibiting significantly higher collection rates and lower percent fines than control sites. A regional increase in sedimentation occurred while nourishment activities were ongoing. Due to concurrent impacts of hurricanes, only one during-construction sampling interval revealed substantially higher collection rates relative to corresponding pre-construction sampling intervals.

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Crawley, A., Kline, D.I., Dunn, S., Anthony, K., and Dove, S. **The effect of ocean acidification on symbiont photorespiration and productivity in *Acropora formosa*.** *Global Change Biology* 16(2): 851-863, 2010.

**Notes**: Ocean acidification is expected to lower the net accretion of coral reefs yet little is known about its effect on coral photophysiology. This study investigated the effect of increasing $CO_2$ on photosynthetic capacity and photoprotection in *Acropora formosa*. The photoprotective role of photorespiration within dinoflagellates (genus *Symbiodinium*) has largely been overlooked due to focus on the presence of a carbon-concentrating mechanism despite the evolutionary persistence of a Form II Rubisco. The photorespiratory fixation of oxygen produces phosphoglycolate that would otherwise inhibit carbon fixation though the Calvin cycle if it were not converted to glycolate by phosphoglycolate phosphatase (PGPase). Glycolate is then either excreted or dealt with by enzymes in the photorespiratory glycolate and/or glycerate pathways adding to the pool of carbon fixed in photosynthesis. We found that $CO_2$ enrichment led to enhanced photoacclimation (increased chlorophyll *a* per cell) to the subsaturating light levels. Light-enhanced dark respiration per cell and xanthophyll de-epoxidation increased, with resultant decreases in photosynthetic capacity ($P_{nmax}$) per chlorophyll. The conservative $CO_2$ emission scenario (A1B; 600-790 ppm) led to a 38% increase in the $P_{nmax}$ per cell whereas the 'business-as-usual' scenario (A1F1; 1160-1500 ppm) led to a 45% reduction in PGPase expression and no change in $P_{nmax}$ per cell. These findings support an important functional role for PGPase in dinoflagellates that is potentially compromised under $CO_2$ enrichment.

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Baskett, M.L., Nisbet, R.M., Kappel, C.V., Mumby, P.J., and Gaines, S.D. **Conservation management approaches to protecting the capacity for corals to respond to climate change: a theoretical comparison.** *Global Change Biology* 16(4): 1229-1246, 2010.

**Notes**: Multiple anthropogenic impacts, including bleaching from climate change-related thermal stress, threaten coral reefs. Protecting coral capacity to respond to the increase in future thermal stress expected with climate change can involve (1) protecting coral reefs with characteristics indicative of greater resistance and resilience to climate change, and (2) reducing other anthropogenic impacts that are more likely to reduce coral resistance and resilience to climate change. Here, we quantitatively compare possible priorities and existing recommendations for protecting coral response capacity to climate change. Specifically, we explore the relative importance of the relevant dynamics, processes, and parameters in a size-structured model of coral and zooxanthellae ecological and evolutionary dynamics given projected future thermal stress. Model results with varying initial conditions indicate that protecting diverse coral communities is critical, and protecting communities with higher abundances of more thermally tolerant coral species and symbiont types secondary, to the long-term maintenance of coral cover. A sensitivity analysis of the coral population size in each size class and the total coral cover with respect to all

parameter values suggests greater relative importance of reducing additional anthropogenic impacts that affect coral-macroalgal competition, early coral life history stages, and coral survivorship (compared with reproduction, growth, and shrinkage). Finally, model results with temperature trajectories from different locations, with and without connectivity, indicate that protection of, and connectivity to, low-thermal-stress locations may enhance the capacity for corals to respond to climate change.

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Carilli, J.E., Norris, R.D., Black, B., Walsh, S.M., and McField, M. **Century-scale records of coral growth rates indicate that local stressors reduce coral thermal tolerance threshold.** *Global Change Biology* 16(4): 1247-1257, 2010.

**Notes**: Coral bleaching, during which corals lose their symbiotic dinoflagellates, appears to be increasing in frequency and geographic extent, and is typically associated with abnormally high water temperatures and solar irradiance. A key question in coral reef ecology is whether local stressors reduce the coral thermal tolerance threshold, leading to increased bleaching incidence. Using tree-ring techniques, we produced master chronologies of growth rates in the dominant reef builder, massive *Montastraea faveolata* corals, over the past 75-150 years from the Mesoamerican Reef. Our records indicate that the 1998 mass bleaching event was unprecedented in the past century, despite evidence that water temperatures and solar irradiance in the region were as high or higher mid-century than in more recent decades. We tested the influence on coral extension rate from the interactive effects of human populations and thermal stress, calculated here with degree-heating-months (DHM). We find that when the effects of chronic local stressors, represented by human population, are taken into account, recent reductions in extension rate are better explained than when DHM is used as the sole predictor. Therefore, the occurrence of mass bleaching on the Mesoamerican reef in 1998 appears to stem from reduced thermal tolerance due to the synergistic impacts of chronic local stressors.

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Mumby, P.J. and Harborne, A.R. **Marine reserves enhance the recovery of corals on Caribbean reefs.** *PLoS ONE* 5(1): art. e8657, 2010. **O/A**

**Notes**: The fisheries and biodiversity benefits of marine reserves are widely recognised but there is mounting interest in exploiting the importance of herbivorous fishes as a tool to help ecosystems recover from climate change impacts. This approach might be particularly suitable for coral reefs, which are acutely threatened by climate change, yet the trophic cascades generated by reserves are strong enough that they might theoretically enhance the rate of coral recovery after disturbance. However, evidence for reserves facilitating coral recovery has been lacking. Here we investigate whether reductions in macroalgal cover, caused by recovery of herbivorous parrotfishes within a reserve, have resulted in a faster rate of coral recovery than in areas subject to fishing. Surveys of ten sites inside and outside a Bahamian marine reserve over a 2.5-year period demonstrated that increases in coral cover, including adjustments for the initial size-distribution of corals, were significantly higher at reserve sites than those in non-reserve sites. Furthermore, macroalgal cover was significantly negatively correlated with the change in total coral cover over time. Recovery rates of individual species were generally consistent with small-scale manipulations on coral-macroalgal interactions, but also revealed differences that demonstrate the difficulties of translating experiments across spatial scales. Size-frequency data indicated that species which were particularly affected by high abundances of macroalgae outside the reserve had a population bottleneck restricting the supply of smaller corals to larger size classes. Importantly, because coral cover increased from a heavily degraded state, and recovery from such states has not previously been described, similar or better outcomes should be expected for many reefs in the region. Reducing herbivore exploitation as part of an ecosystem-based management strategy for coral reefs appears to be justified.

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Burkepile, D.E. and Hay, M.E. **Impact of herbivore identity on algal succession and coral growth on a Caribbean reef.** *PLoS ONE* 5(1): art. e8963, 2010. **O/A**

**Notes**: *Background*: Herbivory is an important top-down force on coral reefs that regulates macroalgal abundance, mediates competitive interactions between macroalgae and corals, and provides resilience following disturbances such as hurricanes and coral bleaching. However, reductions in herbivore diversity and abundance via disease or over-fishing may harm corals directly and may indirectly increase coral susceptibility to other disturbances. *Methodology and Principal Findings*: In two experiments

over two years, we enclosed equivalent densities and masses of either single-species or mixed-species of herbivorous fishes in replicate, 4 $m^2$ cages at a depth of 17 m on a reef in the Florida Keys, USA to evaluate the effects of herbivore identity and species richness on colonization and development of macroalgal communities and the cascading effects of algae on coral growth. In Year 1, we used the redband parrotfish (*Sparisoma aurofrenatum*) and the ocean surgeonfish (*Acanthurus bahianus*); in Year 2, we used the redband parrotfish and the princess parrotfish (*Scarus taeniopterus*). On new substrates, rapid grazing by ocean surgeonfish and princess parrotfish kept communities in an early successional stage dominated by short, filamentous algae and crustose coralline algae that did not suppress coral growth. In contrast, feeding by redband parrotfish allowed an accumulation of tall filaments and later successional macroalgae that suppressed coral growth. These patterns contrast with patterns from established communities not undergoing primary succession; on established substrates redband parrotfish significantly reduced upright macroalgal cover while ocean surgeonfish and princess parrotfish allowed significant increases in late successional macroalgae. *Significance*: This study further highlights the importance of biodiversity in affecting ecosystem function in that different species of herbivorous fishes had very different impacts on reef communities depending on the developmental stage of the community. The species-specific effects of herbivorous fishes suggest that a species-rich herbivore fauna can be critical in providing the resilience that reefs need for recovery from common disturbances such as coral bleaching and storm damage.

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Selig, E.R. and Bruno, J.F. **A global analysis of the effectiveness of marine protected areas in preventing coral loss.** *PLoS ONE* 5(2): art. e9278, 2010. **O/A**

**Notes**: *Background*: A variety of human activities have led to the recent global decline of reef-building corals. The ecological, social, and economic value of coral reefs has made them an international conservation priority. The success of Marine Protected Areas (MPAs) in restoring fish populations has led to optimism that they could also benefit corals by indirectly reducing threats like overfishing, which cause coral degradation and mortality. However, the general efficacy of MPAs in increasing coral reef resilience has never been tested. *Methodology/Principal Findings*: We compiled a global database of 8534 live coral cover surveys from 1969-2006 to compare annual changes in coral cover inside 310 MPAs to unprotected areas. We found that on average, coral cover within MPAs remained constant, while coral cover on unprotected reefs declined. Although the short-term differences between unprotected and protected reefs are modest, they could be significant over the long-term if the effects are temporally consistent. Our results also suggest that older MPAs were generally more effective in preventing coral loss. Initially, coral cover continued to decrease after MPA establishment. Several years later, however, rates of coral cover decline slowed and then stabilized so that further losses stopped. *Conclusions/Significance*: These findings suggest that MPAs can be a useful tool not only for fisheries management, but also for maintaining coral cover. Furthermore, the benefits of MPAs appear to increase with the number of years since MPA establishment. Given the time needed to maximize MPA benefits, there should be increased emphasis on implementing new MPAs and strengthening the enforcement of existing MPAs.

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Sunagawa, S., Woodley, C.M., and Medina, M. **Threatened corals provide underexplored microbial habitats.** *PLoS ONE* 5(3): art. e9554, 2010. **O/A**

**Notes**: Contemporary in-depth sequencing of environmental samples has provided novel insights into microbial community structures, revealing that their diversity had been previously underestimated. Communities in marine environments are commonly composed of a few dominant taxa and a high number of taxonomically diverse, low-abundance organisms. However, studying the roles and genomic information of these "rare" organisms remains challenging, because little is known about their ecological niches and the environmental conditions to which they respond. Given the current threat to coral reef ecosystems, we investigated the potential of corals to provide highly specialized habitats for bacterial taxa including those that are rarely detected or absent in surrounding reef waters. The analysis of more than 350,000 small subunit ribosomal RNA (16S rRNA) sequence tags and almost 2,000 nearly full-length 16S rRNA gene sequences revealed that rare seawater biosphere members are highly abundant or even dominant in diverse Caribbean corals. Closely related corals (in the same genus/family) harbored similar bacterial communities. At higher taxonomic levels, however, the similarities of these communities did not correlate with the phylogenetic relationships among corals, opening novel questions about the evolutionary stability of coral-microbial associations. Large proportions of OTUs (28.7-49.1%) were unique to the coral species of origin. Analysis of the most dominant ribotypes suggests that many uncovered bacterial taxa exist in coral habitats and await future exploration. Our results indicate that coral species, and by extension other animal hosts, act as specialized habitats of otherwise rare microbes in

marine ecosystems. Here, deep sequencing provided insights into coral microbiota at an unparalleled resolution and revealed that corals harbor many bacterial taxa previously not known. Given that two of the coral species investigated are listed as threatened under the U.S. Endangered Species Act, our results add an important microbial diversity-based perspective to the significance of conserving coral reefs.

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Császár, N.B.M., Ralph, P.J., Frankham, R., Berkelmans, R., and Van Oppen, M.J.H. **Estimating the potential for adaptation of corals to climate warming.** *PLoS ONE* 5(3): art. e9751, 2010. **O/A**

**Notes**: The persistence of tropical coral reefs is threatened by rapidly increasing climate warming, causing a functional breakdown of the obligate symbiosis between corals and their algal photosymbionts (*Symbiodinium*) through a process known as coral bleaching. Yet the potential of the coral-algal symbiosis to genetically adapt in an evolutionary sense to warming oceans is unknown. Using a quantitative genetics approach, we estimated the proportion of the variance in thermal tolerance traits that has a genetic basis (i.e. heritability) as a proxy for their adaptive potential in the widespread Indo-Pacific reef-building coral *Acropora millepora*. We chose two physiologically different populations that associate respectively with one thermo-tolerant (*Symbiodinium* clade D) and one less tolerant symbiont type (*Symbiodinium* C2). In both symbiont types, pulse amplitude modulated (PAM) fluorometry and high performance liquid chromatography (HPLC) analysis revealed significant heritabilities for traits related to both photosynthesis and photoprotective pigment profile. However, quantitative real-time polymerase chain reaction (qRT-PCR) assays showed a lack of heritability in both coral host populations for their own expression of fundamental stress genes. Coral colony growth, contributed to by both symbiotic partners, displayed heritability. High heritabilities for functional key traits of algal symbionts, along with their short clonal generation time and high population sizes allow for their rapid thermal adaptation. However, the low overall heritability of coral host traits, along with the corals' long generation time, raise concern about the timely adaptation of the coral-algal symbiosis in the face of continued rapid climate warming.

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Cupido, R., Cocito, S., Barsanti, M., Sgorbini, S., Peirano, A., and Santangelo, G. **Unexpected long-term population dynamics in a canopy-forming gorgonian coral following mass mortality.** *Marine Ecology Progress Series* 394: 195-200, 2009.

**Notes**: Gorgonian corals are long-lived, slow-growing species exhibiting slow population dynamics. Demographic data collected over a period of 11 yr on a small population of temperate, canopy-forming gorgonians dwelling near the edge of the summer thermocline in the northwestern Mediterranean Sea enabled us to assess its responses to the large mortality events that occurred in 1999 and 2003. Changes in population density, size structure and recruitment were examined. Overall, 2101 adult colonies and recruits were observed in situ and 240 photographic plots analyzed. During the first 3 years (2004 to 2006) after the mass mortalities, our measurements revealed a dramatic reduction in the density of healthy colonies (90% suffered total or partial mortality), a shift in the dominant size class towards smaller size and a significant reduction in recruitment. In the following years (2007 to 2008) a significant recovery of injured colonies was found, with almost complete detachment of the dead colonies, a reduction in mortality and a 4-fold increase in recruitment. These findings indicate clear-cut restoration trends of the population, suggesting that recovery after extensive mortality could be faster than predicted by our current knowledge of gorgonian population dynamics.

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Bonin, M.C., Munday, P.L., McCormick, M.I., Srinivasan, M., and Jones, G.P. **Coral-dwelling fishes resistant to bleaching but not to mortality of host corals.** *Marine Ecology Progress Series* 394: 215-222, 2009.

**Notes**: Coral bleaching is becoming an increasingly common disturbance on coral reefs, and although corals can remain bleached for months prior to recovery or death, little is known about how bleaching affects the associated fish community. The present study reports on recruitment and persistence of coral-dwelling fishes during a natural coral bleaching event in Kimbe Bay, Papua New Guinea. Transect surveys revealed that up to 80% of branching coral habitats were affected by bleaching. Healthy (i.e. unbleached), severely bleached, and dying colonies of corymbose *Acropora* spp. were tagged along the reef crest, and resident fish communities were monitored over time. There was no difference in the number of *Pomacentrus moluccensis* that settled on healthy versus bleached corals. Furthermore, the mean number of *P. moluccensis* recruits remaining on

healthy and bleached corals did not differ after 4 wk. In contrast, the number of recruits remaining on dead colonies was lower after 4 wk and the frequency of recruit retention was significantly lower on dead colonies compared to healthy or bleached colonies. Similarly, the abundance of coral-dwelling gobies living on healthy or bleached corals did not decrease significantly over 8 wk, but all gobies disappeared from corals that died from bleaching. These results suggest that *P. moluccensis* recruits do not avoid bleached corals at settlement and that subsequent survival and/or movement of both recruits and adult coral-dwelling gobies is not negatively influenced, provided that the host coral remains alive. However, it is clear that if corals die from bleaching, coral-specialised fishes will quickly disappear, even prior to structural erosion of the habitat.

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Nonaka, M. and Muzik, K. **Recent harvest records of commercially valuable precious corals in the Ryukyu Archipelago.** *Marine Ecology Progress Series* 397: 269-278, 2009. **O/A**

**Notes**: Data, including depth, temperature and substrate, are reported for 143 colonies of 3 species of precious corals (Subclass Octocorallia; Family Coralliidae) collected in the Ryukyu Archipelago from June 2005 to May 2008. Colonies were collected by a commercial harvesting company using a remotely-operated vehicle (ROV) and a manned submersible, and identified tentatively as *Paracorallium japonicum*, *Corallium elatius* and *Corallium konojoi*. The data suggest that these species live deeper in lower latitudes (Amami, Okinawa and Ishigaki regions) than in higher latitudes (southern Kagoshima). Colonies of *C. elatius* may be larger at lower latitudes than at higher latitudes, but with the data available so far this cannot be definitely determined. Size differences may reflect harvest history, not physical or biological factors. (The more southern regions have been exploited more recently than the northern region.) There has not yet been enough data made available to estimate the resource of precious corals remaining in the Ryukyu Archipelago. More studies of their taxonomy and biology, especially growth rates, age and size at fertility and timing of reproduction, and data on biomass are necessary in order to make meaningful estimates.

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Althaus, F., Williams, A., Schlacher, T.A., Kloser, R.J., Green, M.A., Barker, B.A., Bax, N.J., Brodie, P., and Schlacher-Hoenlinger, M.A. **Impacts of bottom trawling on deep-coral ecosystems of seamounts are long-lasting.** *Marine Ecology Progress Series* 397: 279-294, 2009. **O/A**

**Notes**: Complex biogenic habitats formed by corals are important components of the megabenthos of seamounts, but their fragility makes them susceptible to damage by bottom trawling. Here we examine changes to stony corals and associated megabenthic assemblages on seamounts off Tasmania (Australia) with different histories of bottom-contact trawling by analysing 64 504 video frames (25 seamounts) and 704 high-resolution images (7 seamounts). Trawling had a dramatic impact on the seamount benthos: (1) bottom cover of the matrix-forming stony coral *Solenosmilia variabilis* was reduced by 2 orders of magnitude; (2) loss of coral habitat translated into 3-fold declines in richness, diversity and density of other megabenthos; and (3) megabenthos assemblage structures diverged widely between trawled and untrawled seamounts. On seamounts where trawling had been reduced to <5% a decade ago and ceased completely 5 yr ago, there was no clear signal of recovery of the megabenthos; communities remained impoverished comprising fewer species at reduced densities. Differences in community structure in the trawled (as compared to the untrawled) seamounts were attributed to resistant species that survived initial impacts, others protected in natural refugia and early colonisers. Long-term persistence of trawling impacts on deep-water corals is consistent with their biological traits (e.g. slow growth rates, fragility) that make them particularly vulnerable. Because recovery on seamounts will be slow, the benefits from fishery closures may not be immediately recognisable or measureable. Spatial closures are crucial conservation instruments, but will require long-term commitments and expectations of performance whose time frames match the biological tempo in the deep sea.

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Heifetz, J., Stone, R.P., and Shotwell, S.K. **Damage and disturbance to coral and sponge habitat of the Aleutian Archipelago.** *Marine Ecology Progress Series* 397: 295-303, 2009. **O/A**

**Notes**: Video imagery was examined to quantify seafloor disturbance and damage to corals and sponges relative to fishing practices in the central Aleutian Islands of Alaska. Corals and sponges were classified as damaged if they had broken skeletons, missing or broken branches, were torn (i.e. sponges) or detached from the seafloor, or were attached but lying on the seafloor. Disturbance was defined as any alteration to the seafloor or biota caused by fishing gear or natural events. Overall, 14% of

corals and 21% of sponges were damaged, and disturbance was widespread and evident on most video transects. The proportion of damaged corals was significantly less ($p = 0.003$) in areas with little or no bottom trawl fishing versus areas with medium and high intensity bottom trawl fishing. For other gear types, damage was not significantly different among fishing levels. Damage for all corals was 7% in untrawled areas, 7% in low-intensity areas, 14% in medium-intensity areas, and 49% in high-intensity areas. For gorgonians, 5% were damaged in untrawled areas and 23% were damaged in high-intensity areas. For hydrocorals, damage was 10% in untrawled areas and 53% in medium-intensity areas. Hydrocorals were absent from high-intensity areas. About 40% of sea whips were damaged in high-intensity areas versus 1% in other areas. While some protective measures have been implemented to halt the expansion of bottom trawl fishing to unfished areas, the conservation of coral and sponge habitat in fished areas is still of primary concern.

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Bruckner, A.W. **Rate and extent of decline in *Corallium* (pink and red coral) populations: existing data meet the requirements for a CITES Appendix II listing.** *Marine Ecology Progress Series* 397: 319-332, 2009. **O/A**

**Notes**: In June 2007, the US government proposed *Corallium* (pink and red corals) for listing on Appendix II of the Convention on International Trade in Endangered Species (CITES). The proposal was adopted and later overturned due to perceived difficulties in implementing and enforcing a CITES listing and uncertainties on population status. An expert review (Food and Agriculture Organization) questioned whether populations had declined to 20-30% of the historic baseline, the level required for a CITES Appendix II listing. This review used colony abundance and density as surrogates of decline, which may be high (200 to 1300 colonies $m^{-2}$) in the Mediterranean. Yet assessments of decline for colonial organisms should also consider changes in size, since reproductive output and survival increase exponentially with size. Colonies of *C. rubrum* historically achieved heights of 50 cm with complex first, second and third order branching patterns. Today, >90% of colonies in fished areas are 3 to 5 cm tall, <50% are sexually mature and most have only rudimentary branches. Few population data are available for Pacific *Corallium* spp.; however, landings over the last 15 yr have declined from 100-400 to <5 t $yr^{-1}$. Recovery of populations to their natural state may require decades, as colonies in protected areas are less than half their historic size after 20 to 30 yr of protection. Minimum allowable size for harvest should be increased because traditionally determined growth rates appear to underestimate colony age, and corals are being removed long before achieving maximum sustainable yield. 'Boom and bust' cycles of *Corallium* fisheries and dramatic, long-lasting shifts in population demography highlight the need for improved management and trade regulations.

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Hourigan, T. F. **Managing fishery impacts on deep-water coral ecosystems of the USA: emerging best practices.** *Marine Ecology Progress Series* 397: 333-340, 2009. **O/A**

**Notes**: The USA has rich and varied deep-water coral ecosystems. Disturbances from bottom trawls have been well documented in certain habitats and are considered the major threat to deep-water corals in most US regions where such fishing is allowed. Other bottom-set fishing gears (e.g. gillnets and longlines) can also impact these communities. The USA has taken far-reaching action to address these threats to deep-water habitats. Since 2006, the USA has protected nearly 1.8 million $km^2$ of vulnerable benthic habitats from bottom trawling, mostly in the Pacific. Additional major habitat conservation efforts are underway in the US Atlantic. In these efforts, a number of approaches are emerging as best-practices to conserve deep-water corals and other vulnerable marine ecosystems in the deep sea: (1) protecting particularly vulnerable areas, especially seamounts and major identified deep-water coral habitats, from impacts by all bottom-contact gear; (2) defining the current 'footprint' of bottom-trawl and dredge fisheries in partnership with the fishing community, and preventing expansion of these fisheries into deeper waters until they can be surveyed to identify potentially vulnerable habitats; and (3) using fisheries observers and vessel monitoring systems to provide key information that can inform adaptive management and enforcement. In 2006, the Magnuson-Stevens Fishery Conservation and Management Act, the nation's primary fishing law, was amended to explicitly allow protection of deep-sea corals in their own right. These approaches are being incorporated into a national strategic plan to comprehensively study and conserve deep-water coral and sponge ecosystems, and may help inform ongoing international conservation efforts.

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Brock, R., English, E., Kenchington, E., and Tasker, M. **The alphabet soup that protects cold-water corals in the North Atlantic.** *Marine Ecology Progress Series* 397: 355-360, 2009. **O/A**

**Notes**: Canada, the European Union, and the United States, amongst others, recognize the importance of habitat-forming biota such as cold-water corals to a host of associated ecologically and/or commercially important species including fish, crustaceans, and mollusks. These species and the ecological services they provide are important to the peoples surrounding the North Atlantic (i.e. the Atlantic Ocean north of the equator). There are several different legal and/or regulatory tools available to ensure that cold-water corals in the North Atlantic are protected along with the ecological services they provide. Through such tools, many protected areas have been designated or are under consideration in the North Atlantic to protect cold-water coral habitats. Although the designation and labeling varies, e.g. National Marine Conservation Area (Canada), Special Area of Conservation (European Union), or Habitat Area of Particular Concern (USA), all of these designations aim to provide protection into the future to vulnerable habitats like cold-water corals.

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