Climate Adaptation Toolkit for Marine and Coastal Protected Areas

Increase Genetic Resilience

An Adaptation Brief

Overview

Novel techniques to increase genetic resilience include those that involve climate-informed gene pool enhancement or alteration, with the goal of promoting organisms that are better-adapted to future climate stressors. These strategies may play an important role in increasing resistance to climate stressors, accelerating recovery from disturbances, and maintaining critical ecosystem services (e.g., wildlife habitat, water filtration). Novel techniques such as these are also associated with increased risks and must be approached very carefully. Risks may include reduced genetic diversity, increased sensitivity to non-target stressors, introduction of pathogens or predators, and inefficient use of limited resources (e.g., funding, staff capacity). This Adaptation Brief is intended to provide an overview of relevant techniques but should not be interpreted as advocating for their use, which should be evaluated on a case-by-case basis.

Identifying Climate and Non-Climate Vulnerabilities

Potential future changes and associated impacts of climate change on coastal and marine habitats and species include:

Warmer water temperatures

- → **Enhance stress and associated mortality, especially during extreme heat events**
- → **Increase the risk of coral bleaching and disease, potentially resulting in large-scale ecosystem collapse**

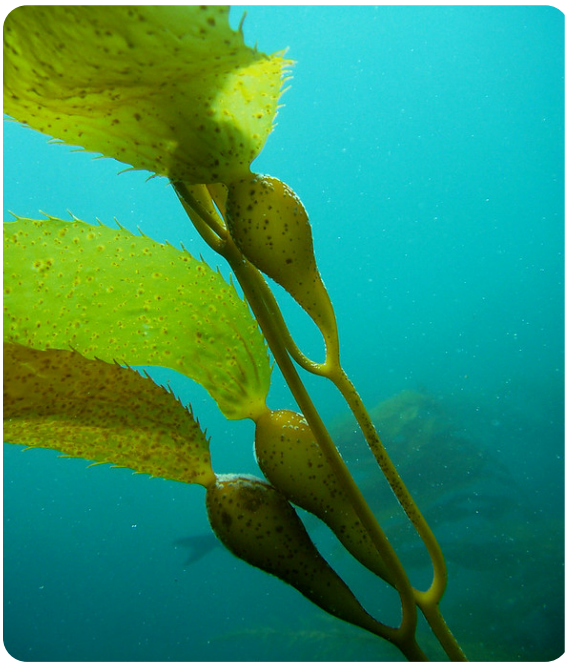
Ocean acidification

- → **Reduces calcification rates in reef-building corals and other marine calcifying organisms**

More frequent and/or severe storms

- → **Increase mortality and reduced cover of keystone species**
- → **Cause damage to habitat structure** (e.g., coral breakage)
- → **Increase turbidity due to suspended sediment, resulting in reduced light and higher nutrient levels that accelerate algal growth**

The impacts of heat stress, ocean acidification, and storm events may be compounded in ecosystems that are already in decline, increasing the risk of phase shifts (e.g., from coral to macroalgae dominance) **and/or sudden ecosystem collapse.**



Claire Fackler/NOAA via Flickr.

Reducing Vulnerabilities through Adaptation Actions

The following are examples of adaptation actions that are considered techniques to increase genetic resilience, with the goal of reducing climate change vulnerability:

EXAMPLE: Transplant genetically-modified corals onto degraded reefs

- ✔ Increases presence of organisms with stress-tolerant traits

EXAMPLE: Seed vulnerable kelp forests with spores from populations that are adapted to higher temperatures

- ✔ Reduces mortality associated with heat stress

EXAMPLE: Increase genotypic diversity in species-poor ecosystems (e.g., seagrass)

- ✔ Accelerates habitat recovery following extreme heat events
- ✔ Associated with increased biomass production, seagrass density, and faunal abundance

Case Studies

The following case studies demonstrate how this adaptation strategy is being used to reduce climate change vulnerability in various regions of North America.

RISK REDUCTION AND RESILIENCE IN THE GREAT MARSH

Essex Bay, Massachusetts, United States

Claude Nozères via Wikimedia Commons (CC BY 4.0).

A research team from Boston University restored three acres of eelgrass in Essex Bay, which is part of the largest wetland-dominated estuary in New England (known as the Great Marsh). After creating a model to determine the most suitable sites for reestablishing and test-transplanting eelgrass in some of the areas suggested by the model, funding was obtained from the National Fish and Wildlife Foundation to implement larger-scale restoration efforts. Starting in 2015, the team hand-transplanted eelgrass, using many different sources of eelgrass from around the region, with the goal of increasing genetic diversity to enhance resilience to current and future stressors. Research in other regions has found that enhancing genotypic diversity in seagrass habitats may support recovery following heat waves and other extreme events. Initial results suggest that the transplants had an 80% survival rate.

These restoration efforts were part of the larger Great Marsh Resiliency Planning Project, which also included salt marsh and dune restoration, hydrodynamic sediment transport and salinity modeling, assessment of hydrological barriers, and community resilience and adaptation planning.

For more information: ***Great Marsh Risk Reduction and Resiliency Enhancement case study***

REGROWING CORAL ALONG THE RIVIERA MAYA, MEXICO

Quintana Roo, Mexico

This collaborative pilot project led by researchers from the *Universidad Nacional Autónoma de México* (UNAM) and SECORE International is focused on developing, testing, and implementing techniques for large-scale reef restoration, with the goal of enhancing the recovery of key coral species struggling against bleaching and disease. These techniques are designed to take advantage of sexual propagation, as naturally occurring spawning events have the potential to produce millions of genetically unique coral recruits that can enhance genetic diversity on the reef and potentially enable natural adaptation to climate stressors.

The project has involved:

- **Collecting eggs and sperm during coral spawning events**, then fertilizing them in vitro, culturing the embryos, and raising the larvae within a lab until they settle on suitable substrates to form juvenile corals.
- **Developing and testing cost-effective ways to culture large numbers of coral larvae within large floating pools** and provide them with suitable substrates for settlement.
- **Outplanting coral recruits and monitoring coral restoration success.**

For more information: ***SECORE International and UNAM's Project Mexico case study***

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Key Resources

- **Australian Institute of Marine Science (AIMS) – Assisted Evolution**: This webpage summarizes the AIMS research efforts regarding assisted evolution, which include projects related to stress conditioning, assisted gene flow, hybridization, modification of algal symbiont communities, and manipulation of other microbes such as bacteria.
- **Engineering Coral to Cope with Climate Change**: This site presents an overview of research taking place at the University of Melbourne in Australia, where researchers are experimenting with genetic modification of coral to increase heat tolerance.
- **New Research to Address Kelp Forest Crisis in California**: This summary of research projects funded jointly by California Sea Grant and the California Ocean Protection Council includes a project on kelp conservation genomics, including assessing genetic variation in bull kelp.
- **The Active Reef Restoration Toolbox is a Vehicle for Coral Resilience and Adaptation in a Changing World**: This peer-reviewed article reviews a range of improved methodologies for coral gardening that are focused on enhancing coral resilience and adaptation to climate change.
- **Increasing Coral Resistance to Bleaching through Microbiome Manipulation**: A controlled aquarium experiment in *Pocillopora damicornis* corals from the Indo-Pacific Ocean found that inoculation with native beneficial microorganisms significantly reduced the impacts of bleaching, resulting in greater resistance to stress from pathogens and high temperatures.
- **Ecosystem Recovery After Climatic Extremes Enhanced by Genotypic Diversity**: This research project in the Baltic Sea documents increased biomass production, seagrass density, and faunal abundance in seagrass beds with higher genotypic diversity, despite near-lethal water temperatures. This suggests that enhancing genotypic diversity in species-poor ecosystems (e.g., seagrass habitats) may support recovery following heat waves and other extreme events.

This brief is based on adaptation strategies and case studies from the **Climate Adaptation Toolkit for Marine and Coastal Protected Areas (MPA Toolkit)**, an online resource created to make climate adaptation planning a simple, direct, and feasible process for marine protected area managers. The MPA Toolkit contains:

- A step-by-step guide to undertaking a Rapid Vulnerability Assessment for marine and coastal areas
- Structured and searchable adaptation strategy ideas with supporting case studies, reports and tools
- Foundational adaptation resources
- Selected experts who can be contacted for technical guidance

Find the Toolkit at https://www.cakex.org/MPAToolkit

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