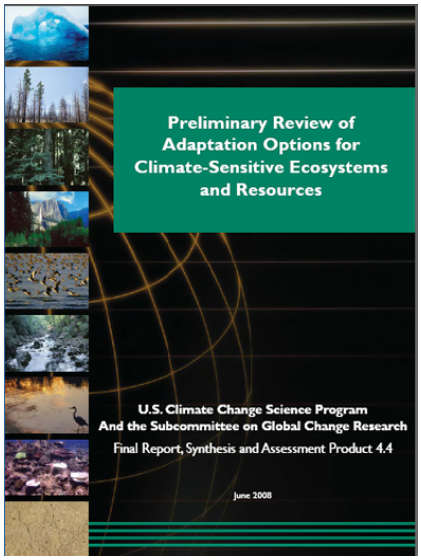

Management Adaptations for Addressing Climate Change Impacts in Marine Environments[1]

In June 2008, the U.S. Environmental Protection Agency, in partnership with the National Oceanic and Atmospheric Administration as well as a number of other U.S. federal agencies, released *Synthesis and Assessment Product (SAP) 4.4: Adaptation Options for Climate-Sensitive Ecosystems and Resources.* Prepared under the auspices of the U.S. Climate Change Science Program, this report reviews strategies that can be used by managers to respond proactively to climate change stressors by promoting resilient habitats in various ecosystems.

Major findings in this document have implications for coral reef management. The report discusses a series of general adaptation approaches to enhance ecosystem resilience, including: reducing anthropogenic stressors; protecting key ecosystem features; maintaining representation; protecting replicate areas; restoring ecosystems; identifying refugia; and relocating organisms. Some of these approaches require working at larger scales and across agencies, territories, and levels of governments. They also highlight the need to directly incorporate climate change into program planning, including re-examination of program goals and authorities in order to create new opportunities for management adaptations. Given the uncertainties associated with the future path of climate change and how climate will interact with other stressors to impact coral reefs, managers need the flexibility and authority to apply dynamic management approaches that can be periodically readjusted as new information becomes available.

The Marine Protected Areas chapter of SAP 4.4 expands upon the general adaptation approaches above and discusses the following key actions for coral reef managers and decision makers to consider:

1) Ameliorate existing stressors & other factors that disrupt marine ecosystems

- This approach is logical, but requires further research using adaptive-management approaches to determine best practices.
- Causes of coral reef disturbances occur at local scales, which are more amenable to area-based management interventions, and regional scales, which require collaborative arrangements across jurisdictions.
- Integrated coastal zone management could be adopted to address land-based sources of nutrients, other pollutants, sediments, etc.

[1] Adapted from: Keller, B.D., S. Airamé, B. Causey, A. Friedlander, D.F. Gleason, R. Grober-Dunsmore, J. Johnson, E. McLeod, S.L. Miller, R.S. Steneck, and C. Woodley, 2008: Marine Protected Areas. In: *Preliminary review of adaptation options for climate-sensitive ecosystems and resources.* A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA, pp. 8-1 to 8-95. http://www.climatescience.gov/Library/sap/sap4-4/final-report/

2) Protect naturally resistant or resilient areas

- Examples include coral reefs in areas of upwelling that reduce thermal stress and in turbid areas where suspended organic material reduces light stress.
- Reefs that still have high coral cover merit protection while investigations are conducted to determine factors contributing to reef health.
- Physiological and ecological factors contributing to resistance and resilience are not well understood and require additional research and monitoring.

3) Establish additional highly protected marine zones

- Sites with high coral cover and low disease prevalence should have a high priority for protective measures as a precautionary approach to management.
- No-take zoning can ameliorate ecosystem disruptions from overfishing and gear impacts.
- Areas with threatened species such as *Acropora palmata* and *Acropora cervicornis* should receive special consideration.
- Marine reserves, in conjunction with comprehensive fishery regulations, appear to be a wise strategy for sustainability irrespective of climate change.

4) Develop networks of MPAs

- Protecting critical areas such as nursery habitat, spawning grounds and aggregations, and apparent climate refugia could enhance resilience.
- Designs that incorporate connectivity – larval dispersal, juvenile and adult movements – should be considered unless spread of pollution or other factors appear to outweigh potential benefits.
- Replicating multiple habitat types to spread risk appears sensible, and adequate representation of all habitats should be considered in designing networks.

5) Support research on connectivity & effectiveness of existing networks of highly protected zones

- Most highly protected zones are small, and many were not designed to form a network, so research efforts should concentrate on appropriately designed MPA networks.
- In addition to modeling connectivity, empirical approaches such as population genetics, genetic markers, and chemical signatures will be particularly beneficial to managers.

6) Integrate climate change into MPA planning, management & evaluation

- MPA monitoring and research that is planned to test the efficacy of MPA design and management is central to adaptive management in the context of climate change.
- Rapid response strategies should be in place to assess extreme events.
- Locations well isolated from local anthropogenic stressors and with histories of exposure to different anthropogenic stressors are essential to studies of climate change impacts.
- Education and outreach programs need to support community awareness of potential climate change impacts and ways to respond.
- Stakeholder participation with MPA managers, e.g., Sanctuary Advisory Councils, is central to building social resilience.

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