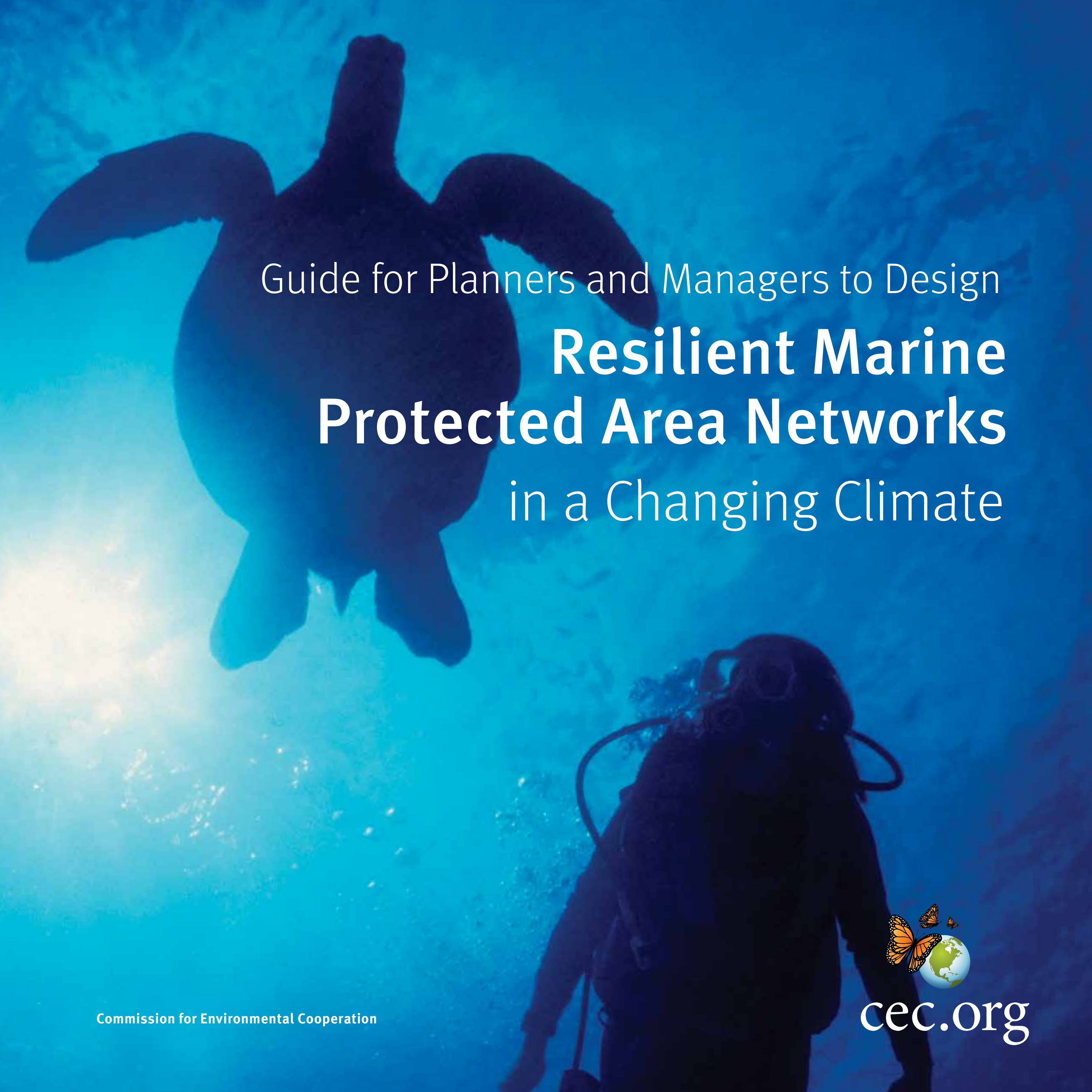

Guide for Planners and Managers to Design

Resilient Marine Protected Area Networks

in a Changing Climate

Commission for Environmental Cooperation

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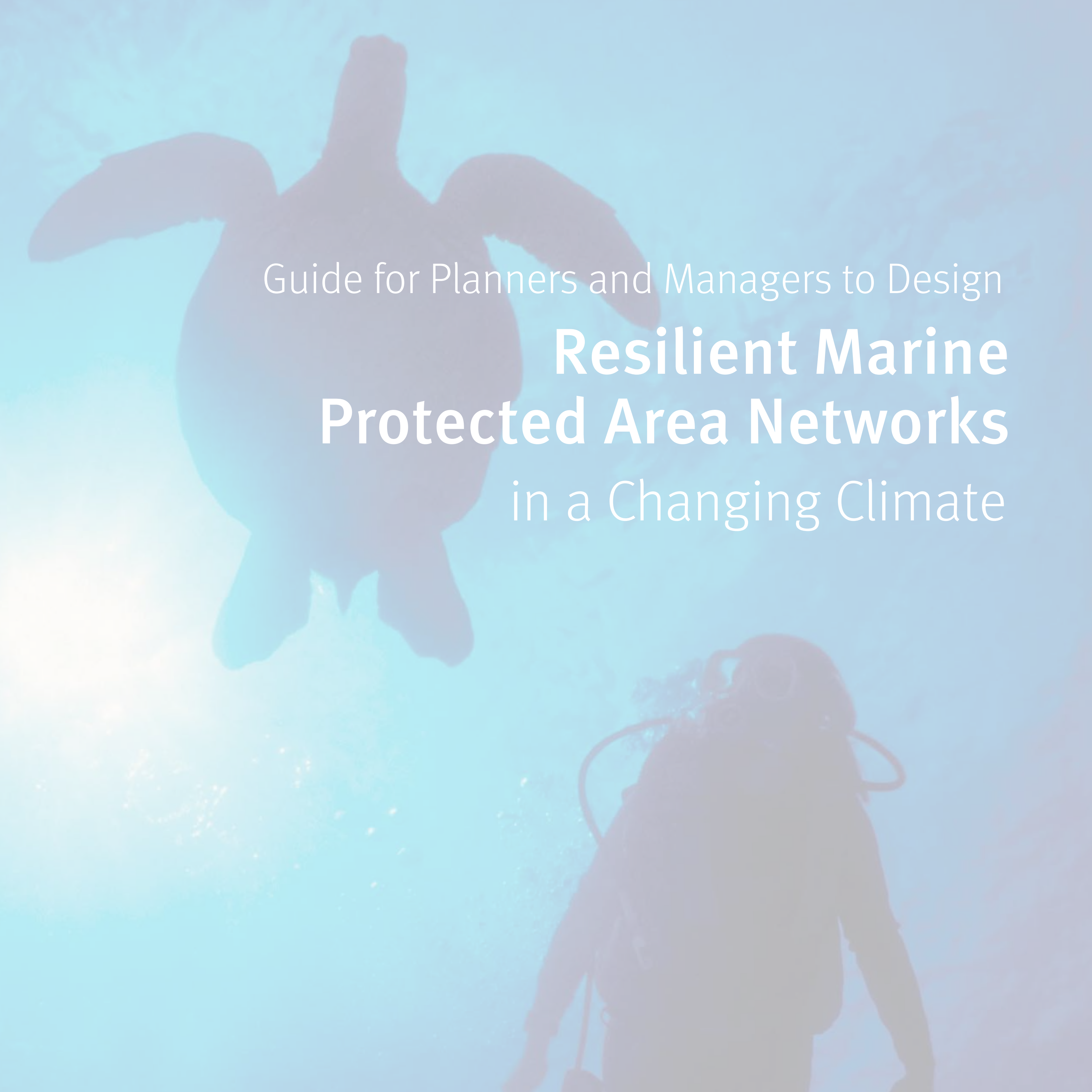
CEC · CCA · CCE

Commission for Environmental Cooperation
393, rue St-Jacques Ouest, Bureau 200
Montréal (Québec) Canada H2Y 1N9
t (514) 350-4300 f (514) 350-4314
info@cec.org / www.cec.org



Guide for Planners and Managers to Design

Resilient Marine Protected Area Networks

in a Changing Climate


Photo: Gary Davis

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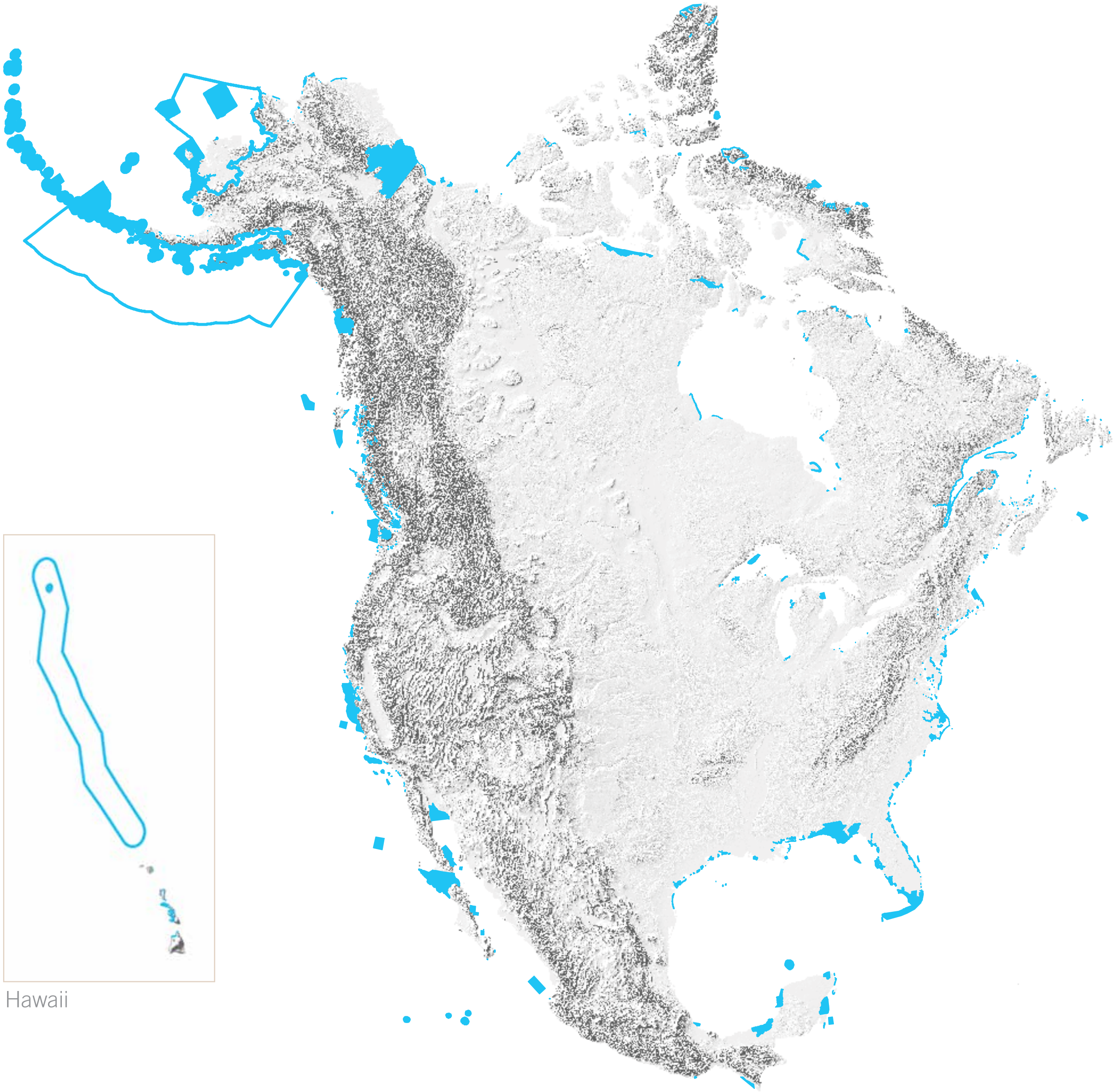


Hawaii

Climate change, along with pollution and overfishing, is one of the great challenges facing North America's shared oceans today. Through the project *Engaging Communities to Conserve Marine Biodiversity through NAMPAN* (North American Marine Protected Areas Network)[1] the Commission for Environmental Cooperation (CEC) gathered scientific information on the impact of climate change on marine protected area (MPA) networks to improve the design and management process for healthier, more resilient oceans.

This guide is intended to help MPA program and network planners and managers meet the climate change challenge by providing four guidelines:

Guideline 1:	Protect Species and Habitats with Crucial Ecosystem Roles or Those of Special Conservation Concern
Guideline 2:	Protect Potential Carbon Sinks
Guideline 3:	Protect Ecological Linkages and Connectivity Pathways for a Wide Range of Species
Guideline 4:	Protect the Full Range of Biodiversity Present in the Target Biogeographic Area

Several sequential steps are suggested under each of the four guidelines, which are intended to provide a practical method or action plan for planners and managers to follow to achieve each goal. A summary table at the end of the guide presents the requirements, potential costs and levels of effort ranked as low, moderate or high to give users a quick sense of the tangible requirements to carry out each action plan.

1. See the CEC project's website at http://www.cec.org/marine and the NAMPAN website at http://www2.cec.org/nampan.

Each step under the guidelines has the following subsections:

Overview: the rationale for the step.

Method: suggested initiatives to achieve the guideline. These are presented as a suite of actions, although they are not necessarily sequential. A number of suggested initiatives in this method section are common to all the guidelines, including a workshop with relevant experts, a literature review of the science relevant to each step, the selection of appropriate models, and engaging stakeholders.

Practical considerations: resource needs and challenges.

Products: the expected documentation (e.g., reports, maps, data) produced or compiled by the end of each step.

Resources: literature, data, organizations, web pages, and other sources likely to be of help in undertaking the steps.

The four overarching guidelines are described more fully in *Scientific Guidelines for Designing Resilient Marine Protected Area Networks in a Changing Climate* (hereafter: the Guidelines, Brock *et al.* 2012). A joint CEC study group developed these guidelines through its NAMPAN *ad hoc* Technical Group and the International Council for the Exploration of the Sea (ICES): Study Group on Designing Marine Protected Area Networks in a Changing Climate (SGMPAN). The Guidelines were developed from a larger report by SGMPAN, *Report of the Study Group on Designing Marine Protected Area Networks in a Changing Climate* (ICES 2011a). This initial report was developed at a workshop held in Woods Hole, Massachusetts, in November 2010. The list of participants from Canada, Mexico and the United States is found in Annex 3 of the Guidelines (Brock *et al.* 2012). The workshop focused on the Atlantic Ocean (from the Western Tropical Atlantic, including the Caribbean Sea and the Gulf of Mexico, northward to and including the Labrador Sea), but participants noted that the guidelines are applicable across North America.

Members of the SGMPAN Study Group, chaired by Robert Brock (United States), Ellen Kenchington (Canada) and Amparo Martinez-Arroyo (Mexico), met again in Woods Hole, Massachusetts, on 9–11 August 2011, to incorporate changes to the SGMPAN report resulting from a six-month peer review of the document and to develop science-based guidelines for designing marine protected area networks, which consider expected climate change impacts on marine ecosystems. The comprehensive SGMPAN report (ICES 2011a) is considered to be the reference document for the Guidelines, with the exception of the oceanographic review that has been updated in the Brock *et al.* (2012) report.

A *Technical Review of Scientific Guidelines for MPA Program/Network Planners and Managers* meeting was held in Ottawa, Ontario, on 13–14 March 2012, to review the Guidelines and draft a synopsis for MPA program and network planners and managers, including examples on how and where the guidelines could be applied. The outcome of this meeting was a draft synopsis for applying the guidelines, which formed the basis for this *Guide for Planners and Managers to Design Resilient Marine Protected Area Networks in a Changing Climate.*

It is envisioned that specialist groups will follow the steps proposed in this guide and provide scientifically based reports that can be used to design a dynamic MPA framework around North America.

Acronyms and Abbreviations

CBD	Convention on Biological Diversity
CEC	Commission for Environmental Cooperation
CO_2	Carbon dioxide
COSEWIC	Canada's Committee on the Status of Endangered Wildlife in Canada
DNA	Deoxyribonucleic acid
EBSA	Ecologically and Biologically Significant Area
EFH	Essential Fish Habitat
ESA	US Endangered Species Act
GIS	Geographic Information System
ICES	International Council for the Exploration of the Sea
MARXAN	Systematic reserve design software
MPA	Marine protected area
NAMPAN	North American Marine Protected Areas Network
NOAA	National Oceanic and Atmospheric Administration
PCA	Priority Conservation Area
SARA	Canada's Species At Risk Act
SGMPAN	Study Group on Designing Marine Protected Area Networks in a Changing Climate
UNEP	United Nations Environment Programme

Introduction

Climate change, resulting from both natural and anthropogenic factors, is expected to affect virtually every aspect of marine ecosystem structure and function, from community composition and biogeochemical cycling, to the prevalence of diseases. Climate can affect all life-history stages through direct and indirect processes. The possible impacts of climate change on marine populations include changes in population dynamics (body size, reproduction), community composition and geographical distributions. Climate change can be expected to affect populations, habitats and ecosystems differently, depending on their underlying characteristics (ICES 2011a, ICES 2011b). Climate change can potentially alter connectivity patterns by changing larval duration times, adult movement patterns and species distributions, for example. Given the importance of connectivity to MPA network design, understanding the influences of climate change on different components of connectivity remains a key research need. Although there are many uncertainties about the rates and spatial structure of future climate change, the probable and potential changes need to be considered in ecosystem management planning.

MPA networks must be designed to be integrated, mutually supportive and focused on sustaining key ecological functions, services and resources. As such, they can provide a mechanism to adapt to and mitigate climate change effects on ecosystems. MPA networks are especially suited to addressing spatial issues of connectivity (e.g., connecting critical places for life stages of key species), habitat heterogeneity and the spatial arrangement and composition of constituent habitats, all of which can contribute to ecosystem resilience. Some of these properties can be supported through the size and placement of protected areas (e.g., abundance and size structure of upper trophic levels, species richness), and the reduction of other stressors such as fishing pressure. Some ecosystem properties may not be amenable to MPAs but can be used to predict their vulnerability to climate change (e.g., phenological matches, flexibility of migration routes, dependence on critical habitats, functional redundancy, response diversity and community evenness) (ICES 2011a).

Ocean governance will need to adjust to reflect a new imperative: maintaining structure, function, processes and biodiversity of ecosystems to enhance resilience to change. A highly coordinated, integrated and adaptive approach to oceans governance will clearly be central to implementing this new imperative, necessitating some mechanism to enhance consistency and coherence across sectors and regions. This will be particularly important with regard to establishing and operating transboundary MPA networks.

Photo: Tyler Jones/IFAS

Guideline 1

Protect Species and Habitats with Crucial Ecosystem Roles or Those of Special Conservation Concern

Step 1

Identify species and habitats with crucial ecosystem roles or those of special conservation concern.

Step 2

Identify the traits of those species/habitats identified in Step 1 that are vulnerable to projected climate change impacts.

Step 3

Determine whether the impacts of climate change on the traits identified in Step 2 can be mitigated by or adapted through MPAs or MPA networks.

Step 4

If impacts on the traits identified in Step 2 can be mitigated by MPAs or MPA networks, specialists should estimate the timescale over which their subject is expected to respond to climate change and trigger a re-evaluation of the boundaries of the MPA, or design the MPA or MPA network to be robust to these changes.

Step 1

Identify species and habitats with crucial ecosystem roles or those of special conservation concern

Overview

The first step in the goal to protect species and habitats with crucial ecosystem roles or those of special conservation concern is to identify the species or habitats that drive or structure ecosystems and ecosystem processes. If the population or coverage of these species dwindles or disappears, as may happen with changing climatic conditions, the ecosystem can suffer far-reaching consequences.

Method

- Identify the species or habitats that are crucial to a particular species, group of species or the functioning of an ecosystem. This may include species or habitats that may differ from those already identified following other network design criteria. For example, examine the aspects of the species and habitats that are not explicitly covered by the Ecologically or Biologically Significant Areas (EBSA) criteria.[2]
- Through a separate process, identify species of special conservation concern.[3]
- Define the crucial role the species or habitat in question plays within the ecosystem.
- Map the location of the target species or habitat.
- Analyze the degree to which the target species or habitat is already protected as a part of an MPA or MPA network (including any in the designation process) and identify any that are linked over larger spatial expanses and timescales.
- Engage stakeholders throughout the process in addressing social and economic considerations.

Practical considerations

- Consider holding a science meeting to bring together national experts on each ecosystem component and gaps in scientific effort.
- Hold meetings, both at regional and local MPA levels.
- Consider using a geographic information system (GIS) to assist in the process.

Products

- A document identifying species and habitats with crucial ecosystem roles, and describing those roles specifically related to the identified species and habitats.
- Map(s) showing the locations of the species and habitats with crucial ecosystem roles (generated via GIS).

Resources

In addition to resources mentioned in the SGMPAN report (ICES 2011a), especially Chapter 6 of the report:

- EBSA criteria (GOBI 2010) and/or the EBSA identification processes in each country.
- Canada's Ecologically Significant Species identification process (DFO 2006) or other processes for identifying priority species in each country.

2. See GOBI 2010 and also http://www.gobi.org/Our%20Work, which provides examples of applying the EBSA criteria.

3. A Species of Special Conservation Concern is any species or subspecies that is undergoing a long-term decline in abundance or that is vulnerable to a significant decline due to low numbers, restricted distribution, dependence on limited habitat resources, or sensitivity to environmental disturbance. These species may or may not have crucial ecosystem roles and may or may not be protected by legislation. See http://www.cec.org/SOE/files/en/SOE_SpeciesCommon_en.pdf.

- Planning documents for existing MPAs.
- Scientific literature and empirical data.
- Local and traditional ecological knowledge.
- Canada's Committee on the Status of Endangered Wildlife in Canada (COSEWIC) reports,[4] Canada's Species at Risk Act (SARA) listed species,[5] the US Endangered Species Act (ESA)[6] and list.

Step 2

Identify the traits of those species/habitats identified in Step 1 that are vulnerable to projected climate change impacts

Overview

The influence of climate change on the location and strength of important oceanographic features may directly affect the abundance and distribution of species and habitats. For example, suitable habitat could easily be modified or lost due to rising sea levels caused by climate change. Similarly, increasing water temperatures can change the size, abundance and distribution of species at specific trophic levels, affecting the entire ecosystem. Ocean acidification will also have important impacts on marine species and habitats. This step involves examining the species and habitats identified in Step 1 and assessing their traits to determine those most vulnerable to the projected impacts of climate change.

Method

- Refer to Annex 1 and Annex 2 of the Guidelines (Brock *et al.* 2012) to apply regional information on climate change impacts.
- Use the SGMPAN report's (ICES 2011a) review of the high-level ecosystem components that are vulnerable to projected climate change impacts (e.g., section 5.2, p. 55-72; Table 5.4.1, p. 75-78) to identify specific traits and vulnerabilities of local species.
- When necessary, and without delaying the MPA network planning process, use predictive models to evaluate the traits.
- Armed with this information and guidance, identify the life-history characteristics and criteria to be used to assess the traits of the species/habitats identified in Step 1 that are vulnerable to projected climate change impacts (for example, increased temperature may cause a northward shift in coral distribution, but only in areas where suitable hard substrate allows settlement; without suitable substrate and appropriate temperature, such corals would be vulnerable to climate change impacts).
- Identify the species'/habitat's level of vulnerability to climate change impacts.
- Identify the temporal and spatial scales at which climate change will have an impact on the target species/habitat.

Practical considerations

- Results from vulnerability assessments should be comparable at the regional scale, so consider holding a regional meeting to agree on the vulnerability assessment methodology.
- Consider holding meetings with local experts in climate change impacts on marine ecosystems to assess vulnerable traits of the species/habitats identified in Step 1.

4. See http://www.cosewic.gc.ca.
5. See http://www.sararegistry.gc.ca/default_e.cfm.
6. See http://www.epa.gov/lawsregs/laws/esa.html.

Products

- A document identifying the traits of species and habitats with crucial ecosystem roles that are vulnerable to projected climate change impacts. Assessment parameters should be explained, and level and temporal and spatial scales of vulnerability should be specified.

Resources

- Annex 1 and 2 of the Guidelines (Brock *et al.* 2012). Annex 2 provides a description of climate change effects on selected ecosystem components.
- See Table 5.4.1 of the SGMPAN report (ICES 2011a). Section 5.2 also focuses on how climate change will affect ecosystem components and identifies data sources to detect those changes.
- Existing predictive models.
- Local and traditional ecological knowledge.

Step 3

Determine whether the impacts of climate change on the traits identified in Step 2 can be mitigated by or adapted through MPAs or MPA networks

Overview

MPAs and MPA networks are unlikely to moderate the vulnerability of all traits to impacts of climate change. This step requires a scientific examination of how protecting the target species or habitat within an MPA or an MPA network might lessen the vulnerability of those traits that are affected by climate change impacts.

Method

- Determine if the species' or habitat's traits vulnerable to impacts from climate change could be addressed (minimized, for example) if that species/habitat were part of an MPA and/or an MPA network that could protect the ecological links or connections among them.
- Review how the existing MPA, or the one in the process of being proposed or designated, was chosen, to see if the present guidelines related to species and habitats align with that area's conservation targets, given potential climate change effects, or if the targets need expanding and/or MPA boundaries need to be changed to reflect the anticipated shift in ecological conditions as a result of climate change impacts.
- Identify the optimal spatial scales for MPAs and MPA networks to protect the vulnerable traits identified for species and habitats with crucial ecosystem roles. There may be a need to consider Guideline 1 in conjunction with Guideline 3 (see below) when determining optimal spatial and temporal scales for network design. Guideline 3 involves protecting ecological linkages and connectivity for a wide range of species. Protecting traits vulnerable at a wider spatial scale, as advised in Guideline 3, might help protect some of the vulnerable traits identified for species/habitats in Guideline 1. MPA network planners and managers should also consider existing MPAs and MPAs in the process of being designated when determining optimal spatial and temporal scales for network design.

Practical considerations

- During meetings at which Steps 1 and 2 are discussed and conducted, determine whether MPAs are the most appropriate tool to address the traits found to be vulnerable to climate change impacts.
- Engage both scientists and managers to contribute to the discussion about whether the MPA is the appropriate tool for addressing climate change impacts.

Product

- A document identifying and describing the traits of species/habitats vulnerable to impacts from climate change that explains if and how MPAs or MPA networks could diminish that vulnerability. If MPAs or MPA networks are not likely to be part of the solution, the document could recommend other approaches to be considered.

Resources

In addition to resources mentioned in the SGMPAN report (ICES 2011a):

- Information on the level of protection and flexibility of various MPA legislative and regulatory tools.

Step 4

If the impacts on the traits identified in Step 2 can be mitigated by MPAs or MPA networks, specialists should estimate the timescale over which their subject is expected to respond to climate change and trigger a re-evaluation of the boundaries of the MPA, or design the MPA or MPA network to be robust to these changes

Overview

Proceed to this step when you have determined that the vulnerability of a species or habitat to impacts of climate change can be addressed by existing MPAs/networks or by establishing an MPA or an MPA network. This step requires estimating the timescale over which the species/habitat is likely to be affected by climate change so that MPA management and boundaries can be re-evaluated to account for future changes.

Method

- Refer to Annex 1 of the Guidelines (Brock *et al.* 2012). Specialists can use this high-level overview of the physical (atmospheric and oceanographic) properties projected to change over the coming decades to estimate the timescale over which their subject (existing MPA/network or potential MPA/network) is expected to respond to climate change and trigger a re-evaluation of the MPA management plan.
- Then, determine the timescale over which the species or habitats in question are expected to respond to climate change.
- Based on climate change models, analyze when the management, including boundaries of an existing MPA, should be re-evaluated to respond to that timescale.
- Use predictive climate change models to analyze which boundaries of a new or existing MPA would help diminish the vulnerability to climate change of certain traits of the species/habitat in question.
- Identify research needs and potential indicators that would help monitor the rate of change in the ecosystem and validate the predictive models.

Practical considerations

- Hold meetings with MPA managers and planners at the relevant geographic scale and scientific experts in climate change and marine ecosystems to perform the exercise required by this step.
- Consider undertaking bilateral negotiations (or if relevant, trilateral ones) for transboundary MPAs to ensure the networks are effective, particularly over longer time spans and spatial scales.

Products

- A document that recommends:
  - whether an MPA or an MPA network boundary (existing or proposed) should be re-evaluated;
  - the spatial areas that, if protected via an MPA, are predicted to be able to help diminish the vulnerability of certain species'/habitat's traits to impacts of climate change;
  - proposes the timeframe during which management and boundaries should be re-evaluated; and
  - identifies the research needs and potential indicators that would help monitor the rate of change in the ecosystem and validate the predictive models.

Resources

In addition to resources mentioned in the SGMPAN report (ICES 2011a):

- Annex 1 of the Guidelines (Brock *et al.* 2012).

Guideline 2
Protect Potential Carbon Sinks

Step 1
Identify habitats and species that function as potential carbon sinks.

Step 2
Describe the carbon flux system, including carbon sources and the sinks identified in Step 1.

Step 3
Determine whether the carbon flux system is vulnerable to impacts from climate change that can be mitigated by MPAs or MPA networks.

Step 4
If impacts on the system from climate change that are identified in Step 3 can be mitigated by MPAs or MPA networks, topical specialists should estimate the trends and timescale over which the impacts are expected and trigger a re-evaluation of the MPA boundaries, or design the MPA or MPA network to be robust to these changes.

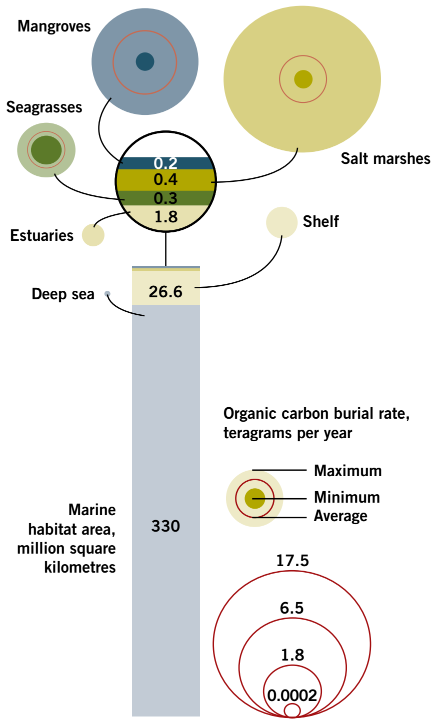
Background on Carbon Sinks

Increasing atmospheric carbon dioxide (CO_2) and other greenhouse gas emissions are contributing to climate change. Helping to mitigate the effects of these emissions are carbon sinks—naturally occurring, healthy coastal and marine habitats and organisms that sequester and store carbon. Carbon sequestration is the capturing of carbon by a carbon sink so that the carbon will not be released into the atmosphere. While all ecosystems sequester carbon to some extent, some marine and coastal habitats and phytoplankton hotspots have been shown to store especially large quantities of carbon. Such marine and coastal habitats and organisms are called blue carbon sinks (see Figure 1).

MPAs and MPA networks are important tools that can help protect carbon sinks so that they can continue to sequester carbon, and also so that their carbon stores are not released back into the atmosphere from habitat loss and degradation due to human activities such as coastal development, aquaculture or dredging. While all carbon sinks are valuable, the most significant for protection include salt marshes, seagrasses and mangroves. These also have other important habitat benefits, and help to shelter and buffer coastal communities from the effects of storms (which are increasing in frequency and severity due to climate change).

The objective of this guideline is to assess the carbon storage capacity of target habitats, identify those areas that represent the best and most stable carbon stores, and ensure no net loss of overall stored carbon. Additional objectives might be to use these areas as research sites to better understand environmental change related to carbon sequestration and as potential sites for restoration and public outreach.

Figure 1 Blue carbon sinks



Sources: Brock *et al.* 2012; Nellemann *et al.* 2009.

Step 1
Identify habitats and species that function as potential carbon sinks

Overview
This step requires a coastal and estuarine habitat assessment. Depending on your geographic area, you may be assessing the extent and integrity of tidal salt marshes, mangroves, seagrasses, kelp forests and phytoplankton hotspots.

Method
- To prepare for this step, study the publications referred to below in the section on resources.
- Map carbon sequestering (carbon sink) ecosystems, habitats and species (i.e., phytoplankton hotspots) using spatial data, including remote sensing, satellite images, bathymetry, historical data, aerial photos and traditional knowledge.
- Measure the area/size of these ecosystems and habitats.
- Develop carbon-budget models to measure the carbon stored in as many of these ecosystems, habitats and species as possible; calculate the carbon storage based on the size/area in question.
- Calculate the carbon storage for different seasonal, temporal and spatial variations.
- If existing areas appear inadequate for storing carbon, restoration and GIS experts should identify and map secondary sites that have the potential to be restored if resources allow (gap analysis).

Practical considerations
- Employ a GIS expert to compile map layer(s).
- Hold a workshop for experts and stakeholders to review the process and map layers, to identify data gaps, historical areas and threats.
- Draw on academic expertise and technical resources (e.g., a local university, where available) in conducting a literature review to help select the appropriate carbon-budget model for the specific geographic region.

Products
- Maps of carbon sequestering habitats and species—actual and potential.
- A document that shows a carbon budget for each ecosystem, habitat and species; areas for potential restoration (if needed); and results of a gap analysis (gaps in protection of identified areas.
- Outreach materials.

Resources
- Existing carbon-budget models.
- Existing maps and spatial data of the targeted area(s).
- Local and traditional ecological knowledge.
- The International Union for the Conservation of Nature publication on managing natural coastal carbon sinks (Laffoley and Grimsditch 2009).
- US National Oceanic and Atmospheric Administration's Blue Carbon initiative.[7]
- United Nations Environment Programme's (UNEP) publication about Blue Carbon (Nellemann *et al.* 2009).
- UNEP-World Conservation Monitoring Centre's report on carbon storage in protected areas (Campbell *et al.* 2008).
- UNEP Blue Carbon Portal.[8]

7. See http://www.habitat.noaa.gov/noaabluecarbonefforts.html.
8. See http://www.bluecarbonportal.org.

Step 2

Describe the carbon flux system, including carbon sources and the sinks identified in Step 1

Overview

Ideally, one would protect all known functioning or restorable marine and coastal carbon sinks within the MPA network planning region—to manage the impacts of climate change on the areas, to ensure that their carbon stores are maintained, and to ensure that they continue to sequester carbon to mitigate climate change effects. In reality, a risk assessment is needed to determine which areas would most warrant protection and the investment of limited resources.

The carbon cycle could be affected by several conditions related to climate change (ocean acidification, warmer temperatures, wind strength) that must be identified locally and regionally both at the ecosystem level and at habitat or species levels. A risk assessment will help to identify the carbon sinks most vulnerable to such climate change effects as sea-level change and storm events, and to the impacts of land- and marine-based human activities. If protected, restored and/or enhanced, these areas can act as tools to mitigate climate change. The risk assessment exercise will allow prioritization of which carbon sinks require immediate protection. Subject to available resources, carbon sinks that are not currently at risk can also be protected proactively, to ensure that they can continue to provide mitigation benefits in the long-term. While MPAs are one option, other tools such as provincial/state habitat management plans could also be used to protect carbon sinks.

Method

- Produce an integrated map of the targeted biogeographic area or marine ecoregion that includes the most important marine and coastal carbon sinks.
- Model indicator data (e.g., sea-level rise, storm surge, salinity models, freshwater influx, temperature) for climate change impacts on the target area.
- Collect and compile geospatial socioeconomic data on human activities that could affect the marine area in question (e.g., land-use change, oil/gas development, coastal development).
- Conduct a literature review to select the appropriate risk assessment methodology.
- Identify or develop a risk assessment methodology (e.g., pathway of effects models, a cost-benefit analysis, or MARXAN[9]).
- Conduct a risk assessment of the vulnerability of the target area to current and anticipated threats, including land- and marine-based human activities as well as climate change impacts, so as to identify those most amenable to mitigation efforts or in most immediate need of protection.

Practical considerations

- Engage a GIS expert to compile the map layers.
- Consider drawing on academic expertise and technical resources (e.g., a local university, where available) to help select or design indicators of the impacts of both climate change and land- and marine-based human activities on the target area, and to identify an appropriate risk assessment methodology.
- Hold an experts' workshop to conduct a risk assessment, and have the results peer-reviewed.

9. For MARXAN, see http://www.uq.edu.au/marxan/index.html?page=77664&p=1.1.7.3.

Products

- Maps of all known and functioning carbon sinks, as well as sites that could be enhanced, with their vulnerability ranking indicated.
- No net loss of carbon analysis: maps or other documents showing the results of a risk assessment prioritizing for mitigation, protection or restoration of areas that are the best, most stable carbon stores to ensure no net loss of carbon.

Resources

- Risk assessment tools.
- Decision-support tools (e.g., MARXAN).

Step 3

Determine whether the carbon flux system is vulnerable to impacts from climate change that can be mitigated by MPAs or MPA networks

Overview

Intact marine and coastal carbon sinks represent a carbon sequestering system that serves society by reducing carbon in the atmosphere and sheltering coastal communities. To ensure the continuity of these functions, the most important known carbon sinks may need protection. Some may already be within MPAs, some may be protected through stewardship and sound management, but others may require stronger protection. The system of carbon sinks is linked ecologically to the broader network of terrestrial and marine protected areas. Considered in the context of an MPA network, efforts would be focused on ensuring: 1) that the priority carbon sink sites (identified in Step 2) are protected; and 2) that enough of them are protected (number/size). This step could include enhancing existing areas and potentially restoring degraded/historic areas.

Method

- Identify the carbon sinks within existing MPAs.
- Conduct a gap analysis (identification of areas in need of protection).
- Identify and protect additional areas according to the priorities set out in Step 2, as resources allow.
- If necessary, adjust MPA boundaries to allow for carbon-sink restoration and enhancement activities.
- Where relevant, map the adjusted MPA boundaries, the gaps in protection, the entire carbon-sink system and links to other protected areas.
- Ensure that each relevant MPA management plan includes a conservation objective to protect carbon stores and enable carbon sequestration to continue within the area, with appropriate management activities to accomplish it.
- If feasible, establish a community of experts to promote best practices and develop cross-cutting monitoring and management protocols.
- Develop outreach materials about the role of coastal and open-ocean ecosystems, habitats and species as carbon sinks that help mitigate climate change to encourage sound management of the areas.
- Engage stakeholders throughout the process to address social and economic considerations.

Practical considerations

- Engage a GIS expert to add the carbon sink system to the existing map of MPA network sites and gaps.
- For each site, hold a meeting of MPA managers and planners to review and revise the management plan to include carbon storage conservation objectives and activities.
- Set up an experts' network and hold annual meetings.

Products

- Maps of existing MPAs that sequester/store carbon factored into MPA network design, where possible.
- Carbon sink maps that show prioritized carbon sink network gaps to be filled with additional MPAs or other marine spatial conservation tools.
- An established community of carbon sink experts.

Resources

See resources mentioned in Steps 1 and 2.

Step 4

If impacts on the system from climate change that are identified in Step 3 can be mitigated by MPAs or MPA networks, topical specialists should estimate the trends and timescale over which the impacts are expected and trigger a re-evaluation of the boundaries of the MPA, or design the MPA or MPA network to be robust to these changes

Overview

Predictive models as well as *in situ* monitoring will increase our understanding of carbon production and storage processes and enable us to develop better management programs to maximize carbon uptake within the MPA network. The objective is to develop a monitoring protocol for the system of MPAs within appropriate spatial expanses and timescales, to ensure the carbon sequestering function is maintained optimally over time. A second objective is to improve the carbon-budget models over time with *in situ* data as part of an adaptive management approach.

Method

- Support research on carbon production and storage processes in the target MPAs, using predictive models as well as *in situ* monitoring.
- Seek the advice of a relevant scientist(s) to develop an appropriate network-level protocol to measure site-level carbon sequestration. Develop a monitoring protocol to monitor the integrity of those ecosystems, habitats and species that sequester carbon (i.e., for tidal salt marshes, mangroves, seagrasses, kelp forests and phytoplankton), including indicators such as meteorological, ecological, biogeochemical variables, extent of area and fragmentation of area. Habitat-specific monitoring protocols may be needed.

- Integrate the carbon system monitoring protocol into the existing MPA network monitoring protocol and activities.
- Carry out monitoring as feasible; collect and analyze *in situ* data.
- Refine the carbon-budget models with *in situ* data as they become available.
- Seek the involvement of coastal communities in monitoring, as appropriate.

Practical considerations

- Draw on academic expertise and technical resources (e.g., a local university, where available) to help develop the monitoring protocol and indicators or otherwise engage scientific expertise for this task.
- Integrate the monitoring protocol for the carbon system into the overall MPA network monitoring protocol, seeking efficiencies.
- Train volunteer community members able to participate in monitoring activities.

Products

- A document that outlines the carbon monitoring protocol.
- *In situ* monitoring data to improve carbon budget (sequestration) models.
- A revised MPA network monitoring protocol that integrates the new carbon protocol.
- Site-specific MPA management plans that include carbon monitoring activities.
- Training programs for local communities.

Resources

See resources mentioned in Steps 1 and 2.

Guideline 3

Protect Ecological Linkages and Connectivity Pathways for a Wide Range of Species

Note: The Guidelines (Brock *et al*, 2012) separate out the building of models of adult movement and larval transport into two separate steps. As the process for conducting these steps is similar, they are combined here, and the subsequent numbering re-ordered.

Step 1

Identify potential ecological linkages and physical drivers such as prevailing currents.

Step 2

Build and apply dynamic models of adult movement and migration, as well as larval transport, to test hypothesized connectivity among areas, including potential source-sink regions and migratory patterns.

Step 3

Determine whether the critical linkages and pathways identified above are vulnerable to climate change impacts and can be mitigated by MPAs or MPA networks.

Step 4

If the impacts on the linkages and pathways identified above can be mitigated by MPAs or MPA networks, specialists should estimate the timescale and distances over which the impacts may be expected and trigger a re-evaluation of the boundaries of the MPA, or design the MPA or MPA network to be robust to these changes.

Step 1

Identify potential ecological linkages and physical drivers such as prevailing currents

Overview

The fluid nature of marine ecosystems allows geographically separated populations and regions to be connected through exchange of individuals. MPAs and MPA networks are management tools that help maintain, optimize and preserve such ecological connectivity. The marine ecological regions of North America have been identified, and North American prevailing currents exist in the northeastern Pacific and in northwestern Atlantic Oceans. Linkages are known for some migratory species among these ecological regions (mammals and seabirds, in particular) and, to a lesser extent, for pelagic species, benthic species, and other species with larval dispersals. Population connectivity within marine species is a key characteristic with direct relevance to the scale and spacing of MPA networks. Also, organisms that actively move across the landscape and connect habitats in space and time ('mobile link organisms') may contribute strongly to marine ecosystem resilience, while flexibility in migration routes for migratory species represents a critical population characteristic that could influence adaptability to climate change effects. Trophic interactions also need to be considered since they maintain food web connections within and among ecosystems. Researching the effects of climate change on the relative importance of top-down and bottom-up forcing factors is critical to understanding trophic connectivity and the resilience of ecosystems (Brock *et al.* 2012).

Method

- Conduct a literature review of the potential ecological linkages and physical drivers, including critical habitats and water movements.
- Draw on existing EBSA identification work. Where no information exists: identify spawning aggregations, larval settlement locations, feeding grounds, and other important habitats for representative species of interest through workshops and interviews (e.g., with divers, fishermen, scientists and indigenous communities).
- Track different species, at different stages and different scales, using telemetry, mitochondrial DNA, isotopes, and other techniques.
- Look for patterns over time.
- Produce maps showing the links and patterns for spawning aggregation, larval settlement locations, feeding grounds, and other important habitats.
- Engage stakeholders throughout the process to address social and economic considerations.

Practical considerations

- Engage a GIS expert to compile map layer(s).
- Draw on academic expertise and technical resources (e.g., a local university, where available) to help conduct the literature review or otherwise engage a scientific expert for this task.
- Hold a workshop to glean information from users and observers of the marine ecosystems.
- The hurdles might include a lack of funding or expertise, extent of traditional knowledge, political will and intent of existing legislative tools.

Products

- Documentation of narrative descriptions about the links and patterns of relevant linking phenomena.
- Documentation of the data from tracking methods, which also shows the patterns detected.
- Maps showing the linking patterns and locations of processes that enhance connectivity.
- A network of experts (scientists, fishermen, indigenous communities, MPA managers and planners) established from workshops and interviews.

Resources

- Downloadable government remote sensing data files for currents and drifter data.
- COSEWIC-published status reports for species at risk (Canada).[10]
- National Commission for Knowledge and Use of Biodiversity (*Comisión Nacional para el Conocimiento y Uso de la Biodiversidad*—Conabio) conservation area gap analysis in Mexico[11] (e.g., protected areas, EBSAs, priority areas).
- Existing EBSA identification reports.[12]
- Tagging data and reports.
- Existing NAMPAN Pacific Priority Conservation Areas (PCAs).[13]
- Mesoamerican Reef System Reports.[14]
- Essential fish habitat (EFH) designations.[15]
- Local and traditional ecological knowledge.

Step 2

Build and apply dynamic models of adult movement and migration, as well as larval transport, to test hypothesized connectivity among areas, including potential source-sink regions and migratory patterns

Overview

This step involves using potential ecological linkages (sources, sinks and migratory patterns) identified in Step 1 to develop biophysical models to ascertain critical linkages and pathways according to the network's objectives. Most marine ecosystems maintain strong connections with adjacent and distant ecosystems through the movement of larval, juvenile and adult organisms across ecosystem boundaries. This step is key to demonstrating the need for MPA networks, including transboundary networks, yet there are still many knowledge gaps. A large amount of information is needed to model an entire ecosystem, including movements within and between them. Larval transport is a mechanism of biological connectivity that is dependent on biophysical features and phenomena, such as prevailing currents. Larval movement, especially the extent of larval spillover from MPAs into surrounding waters, is also an important consideration in MPA

10. Available at http://www.cosewic.gc.ca/.
11. See http://www.conabio.gob.mx/.
12. See http://www.iucn.org/knowledge/publications_doc/publications/?8623/Ecologically-or-biologically-significant-areas-in-the-pelagic-realm--examples-and-guidelines--workshop-report.
13. See interactive map at http://www2.cec.org/nampan/pcas.
14. See http://www.icran.org/action-mar.html.
15. See http://www.habitat.noaa.gov/protection/efh/index.html; EFH designations are found on the websites for the regional offices (e.g., http://www.nero.noaa.gov/hcd/webintro.html). The NOAA Habitat Mapper shows all EFHs (http://www.habitat.noaa.gov/protection/efh/habitatmapper.html).

network design. Modeling larval transport and adult movement involve two different life stages. This implies different monitoring techniques, models, methods, expertise and infrastructure needs (e.g., satellite imagery versus chemical techniques). Research is still required on the movements and habitat preferences of some transboundary species shared in North America (migratory or others, including species that have sessile adults and pelagic larvae). Close collaboration is required among Canada, Mexico and the United States to fully understand these movements.

Method

- Study the life history characteristics of the species of interest.
- Collect existing monitoring data (such as tagging, genetic and biogeochemical information) to infer adult and larval movement.
- Collect directed monitoring data according to network design, legislation, modeling input and MPA manager needs.
- Use the data to help design and validate biophysical models of adult and larval movement and migration patterns.
- Construct spatially explicit models of oceanic current circulation coupled with biological models of the organism to understand the dispersal and movement of larvae.
- Design a biophysical model based on desired output in addition to available input data.
- Assess the model output in terms of spatial analysis, connectivity, key areas and overlap.
- Conduct bilateral and/or trilateral analyses of model output, including probabilities of species retention versus dispersal.

Practical considerations

- Draw on academic expertise and technical resources (e.g., a local university, where available) to provide the life histories of relevant species.
- Hold a workshop to design the biophysical models.
- Engage a GIS expert to produce the maps.
- Because different life stages can be transboundary, political and legal hurdles will also require special consideration.

Products

- A document presenting the dynamic models of spatial and temporal connectivity for larvae, juveniles and adults of relevant species, including probabilities of retention versus dispersal.
- Connectivity maps, including: i) those demonstrating linkages between sources and sinks and ii) migrations between feeding grounds, breeding grounds, nurseries, and other important habitats.
- Documentation of bilateral- and/or trilateral-level analyses of marine connectivity.

Resources

- Existing models and literature of highly migratory species and source-sink patterns for commercially fished species.
- Existing models and literature on larval behavior, larval dispersal and their relation with sea currents.
- Existing literature on collaborative monitoring methods.
- Online trackers of tagged species (e.g., mammals, sharks, billfish, tuna). Tracking tools can be dart tags, acoustic, telemetric, satellite, and more.
- Data from surveys of larvae in the final stages before settling can be used for *in situ* measurement of cohorts.
- Ichthyoplankton surveys.
- Fishery management plans and catch statistics (analyzed for trends).
- Stock assessment reports.
- Fisheries-dependent and fisheries-independent research.

Step 3

Determine whether the critical linkages and pathways identified above are vulnerable to impacts from climate change that can be mitigated by MPAs or MPA networks

Overview

Once potential ecological linkages have been identified and sufficient models developed, it will be easier to assess how to configure an MPA network that enhances connectivity. The objective is to optimize connectivity between MPAs by protecting areas of high biological productivity and key life-stage habitats that are important for maintaining and enhancing ecological linkages. For example, a stepping-stone approach can be used to protect known key habitats of migratory s pecies that are spaced far apart (such as a key feeding and breeding grounds for whales). A well-designed MPA network that incorporates representative habitats, EBSAs and replication, and that builds on the conservation value of other management measures in the environment, will ensure some degree of connectivity. The next step is to ascertain if climate change impacts are expected to interrupt or alter critical linkages and pathways and if MPAs and MPA networks can be designed to diminish those effects. If possible, known food webs can be modeled to help the analysis.

Method

- Monitor changes in migratory routes, feeding grounds, spawning sites, displacement sites, and other important habitats through literature reviews and interviews with fishermen, divers and other observers.
- Conduct biophysical modeling.
- Among the often conflicting climate change models, choose one that is broadly accepted by the scientific community and whose assumptions correspond with the legislated objectives of the MPAs in the network.
- Extrapolating from existing knowledge and results of the climate change models, produce a map predicting the potential shifts in ecological connections.
- Refine the locations of current and future EBSAs according to the outcomes of the exercise.
- Note how the map with predicted shifts in ecological connections overlaps with current and planned MPA boundaries.
- Based on biophysical modeling and monitoring results (i.e., vertical and horizontal anomalies), consider whether MPAs or MPA networks could be expanded or shifted to incorporate migratory routes, feeding grounds, spawning sites, and other important habitats that may have moved or are expected to move due to climate change.
- Modify the MPA or MPA network design to correspond to the needs for expansion or shifts in boundaries identified by the modeling and monitoring results.

Practical considerations

- Engage relevant scientists to conduct the various analyses and monitoring required.
- Hold a workshop to design the biophysical and climate models.
- Engage a GIS expert for the remote sensing data collection and to produce the maps.
- Conduct interviews with observers in the marine ecosystem in question.

Products

- Documentation of narratives from observers.
- An extrapolated predictive map of shifting ecological connections.
- Documentation of how the locations of current and future EBSAs have been refined.

Resources

- Existing biophysical and climate models.
- Downloadable remote sensing data files (e.g., government holdings).
- COSEWIC-published status reports for species at risk (Canada).[16]
- Conabio conservation area gap analysis in Mexico[17] (e.g., protected areas, EBSAs, priority areas).
- Existing EBSA identification reports.[18]
- Existing NAMPAN Pacific priority conservation areas (PCAs).[19]
- Mesoamerican Reef System Reports.[20]
- Essential Fish Habitat (EFH) designations.[21]

Step 4

If the impacts on the linkages and pathways identified above can be mitigated by MPAs or MPA networks, specialists should estimate the timescale and distances over which the impacts may be expected and trigger a re-evaluation of the boundaries of the MPA, or design the MPA or MPA network to be robust to these changes

Overview

In this step, models from the previous steps will be used to identify which MPA management, boundaries, or MPA network designs should be adjusted to protect certain life-history stages or species-specific behaviors critical to providing linkages and pathways in cases where spatial and temporal use patterns may shift as a result of climate change. The proposed adjustments to MPA boundaries or the design of new MPAs to make them more robust to the impacts of climate change will depend on the direction and extent of the expected temporal and spatial changes to the linking phenomenon. Different species and various life-history stages may respond in dissimilar ways to stressors induced by climate change. Therefore, optimizing the spatial and temporal adjustments in the MPA boundaries and designs may require prioritizing those species most in need of habitat protection.

16. See http://www.cosewic.gc.ca/.
17. See http://www.conabio.gob.mx/.
18. See http://www.iucn.org/knowledge/publications_doc/publications/?8623/Ecologically-or-biologically-significant-areas-in-the-pelagic-realm--examples-and-guidelines--workshop-report.
19. See interactive map at: http://www2.cec.org/nampan/pcas.
20. See http://www.icran.org/action-mar.html.
21. See http://www.habitat.noaa.gov/protection/efh/index.html; EFH designations are found on the websites for the regional offices (e.g., http://www.nero.noaa.gov/hcd/webintro.html).

Method

- For each species identified in the previous steps as being critical to linkages and pathways between MPAs and also vulnerable to climate change impacts, determine the direction and extent of the spatial and temporal ecological shifts due to climate change. This analysis could take place at the same time as the exercise in Step 3 to predict the potential shifts in ecological connections.
- Identify shifts that have already taken place in biophysical gradients, such as salinity, temperature, depth.
- Using the models already produced in previous steps, overlay the climate change models with the ecological connectivity models.
- To determine how to optimize the MPA or MPA network, use the biophysical models from previous steps to adjust the MPA boundaries and modify the MPA network design to produce the greatest overall ecological benefit (very similar to Step 3).
- Identify the timescale for the expected changes, based on the speed of species-specific adjustments to climate change and on the speed of climate change impacts according to climate change models (i.e., temperature tolerance ranges, pelagic larval durations).
- Consider the socioeconomic, legal and political factors that could play substantial roles in balancing costs and benefits of new or adjusted MPAs and MPA networks and find ways to overcome obstacles.
- Devise an outreach plan to explain the purpose of the adjusted MPA boundaries and MPA networks. This action is particularly important when short-term changes are needed or in cases when new MPAs or MPA networks are being designed.
- Engage stakeholders throughout the process to address social and economic considerations.

Practical considerations

- Engage scientific experts to help determine the direction and extent of the spatial and temporal ecological shifts due to climate change.
- Engage a GIS expert for the map layers.
- Hold a workshop with MPA planners to discuss how to adjust boundaries or incorporate new features into MPA and MPA network designs.
- Examine the legal, socioeconomic and political considerations for changing the boundaries or establishing new MPAs or MPA networks, including across international boundaries.

Products

- A map of the spatial layout of proposed additions and/or boundary changes to existing MPAs and MPA networks.
- A time-bound action plan for undertaking the proposed changes.
- Stakeholder meetings to discuss how to implement the action plan.

Resources

- Existing biophysical and climate models.
- MARXAN[22] or other MPA network design optimization software packages.
- GIS shapefiles for all existing MPAs and MPA networks.
- GIS shapefiles for important habitats (e.g., EFH, EBSA, critical habitats) and pathways (e.g., currents, migratory routes).

22. See http://www.uq.edu.au/marxan/index.html?page=77664&p=1.1.7.3.

Guideline 4
Protect the Full Range of Biodiversity Present in the Target Biogeographic Area

Step 1
Identify biodiversity in the target biogeographic area or marine ecoregion.

Step 2
Assess the projected impacts from climate change as stressors and threats to the biodiversity of those areas identified in Step 1.

Step 3
Determine whether the impacts on biodiversity from climate change (Step 2) can be mitigated by MPAs or MPA networks.

Step 4
Assuming MPAs or MPA networks can mitigate the impacts from climate change identified in Step 3, topical specialists should predict the spatial/timescale over which their subject is expected to respond and trigger a re-evaluation of the MPA boundaries, or design the MPA or MPA network to be robust to these changes.

Step 1

Identify biodiversity in the target biogeographic area or marine ecoregion

Overview

Biodiversity includes not only the world's species, with their unique evolutionary histories, but also genetic variability within and among populations of species and the distribution of species across local habitats, ecosystems, landscapes and whole continents or oceans. To capture the full range of biodiversity present in an MPA network, it is important to protect representative samples of each habitat type in a biogeographic area as well as all species and habitats that appear to play key roles in the ecosystem. To identify representative habitat samples, designers of an MPA network should classify habitats (according to a customized local scheme or using standardized classification systems such as NOAA's Coastal and Marine Ecological Classification Standard[23]) throughout the study area, identify the minimum number or units of habitat types for inclusion in the MPA network, and select for protection individual habitat units that best represent the classification type. A combination of biological and sociopolitical realities, however, will inevitably constrain biodiversity management options. The predominance of certain ecosystems and/or a distinct suite of oceanographic or topographic features is likely to determine species' composition. The dominant biogeographic forcing agents that define the ecoregions vary from location to location but may include isolation, upwelling, nutrient inputs, freshwater influx, temperature regimes, ice regimes, exposure, sediments, currents, and bathymetric or coastal complexity.

Method

- Assemble the available geospatial information on the region's geomorphology, oceanographic features, and species distribution from invertebrates to seabirds. It is important to define inputs carefully (e.g., core habitat areas of key species).
- Use the best information currently available.
- Identify the key gaps in required information.
- Continue to emphasize the need to improve the data on habitat characteristics.
- Identify other input parameters, including conservation targets. This can be an iterative process with stakeholders.
- Use decision support tools (such as MARXAN[24]) to generate options.
- Engage stakeholders throughout the process to address social and economic considerations.

Practical considerations

- If needed, hold an experts' workshop to fill information gaps (e.g., participatory GIS).
- Work with trained staff and resources to use the decision-support tools; engage experts and stakeholders in the process.
- Consider working with professionals who provide training in the use of decision support tools (e.g., PacMARA[25]).
- Consider local and traditional ecological knowledge to fill additional information gaps.

Products

- A habitat classification scheme that provides the subunits for representativity in the network.
- A document that shows the preferred MPA network options generated by MARXAN or a similar decision support tool. The recommended options should include spatially optimized layers of areas of high conservation value (based, for example, on habitat type, geomorphology, oceanographic features).
- Additional products, including maps of individual data layers and documentation (such as a Habitat Atlas).

23. See http://www.csc.noaa.gov/digitalcoast/_/pdf/CMECS_Version%20_4_Final_for_FGDC.pdf .
24. See http://www.uq.edu.au/marxan/index.html?page=77664&p=1.1.7.3.
25. See http://pacmara.org/.

Resources

- Great Barrier Reef zoning process (Day 2002).[26]
- Technical report for Scotian Shelf (Horsman *et al.* 2011).
- Mexico's terrestrial and marine gap analysis (March 2005.
- Parks Canada Gwaii Haanas Study.[27]

Step 2

Assess the projected impacts from climate change as stressors and threats to the biodiversity of those areas identified in Step 1

Overview

This step is a diagnosis of how climate change is likely to affect habitat types and other biodiversity aspects of the marine ecoregion, as identified in Step 1. Managers will need to identify information on physical trends and projections of climate change impacts on the biogeographic area, marine region or habitat subunit. Native species diversity, connectivity and habitat heterogeneity are critical for maintaining marine ecosystem functioning, so climate change impacts on these characteristics need to be studied. The traits least resistant to environmental stress need to be identified.

Method

- Refer to Annex 1 and Annex 2 of the Guidelines (Brock *et al.* 2012) to apply regional information on climate change impacts.
- Analyze expected climate change impacts on habitat types. Some aspects, like substrate and geomorphology (e.g., canyon, banks and basins) are unlikely to change. Others, such as temperature regimes and biogenic habitats (e.g., coral reefs, oyster reefs, sponge reefs, kelp beds, eelgrass beds) are more likely to be affected.
- Use this information on expected climate change impacts and the traits most vulnerable to them in Steps 3 and 4 to help design the MPA network best able to protect biodiversity.

Practical considerations

- Develop partnerships with academic and technical experts (e.g., a local university, where available) and with other science partners to get additional expertise about expected climate change impacts on the full range of species and habitats.
- Consider holding an expert workshop to develop scientific consensus on diversity indices at different spatial scales.

Products

- A document that shows the matrix of habitat types, showing their likelihood to be impacted by climate change parameters (e.g., adapt Annex 2 of the Guidelines [Brock *et al.* 2012] to show habitat types).
- The documentation of the overall assessment of the habitat type's vulnerability to climate change, based on all parameters.

Resources

- Table A1.3 from Annex 1 of the Guidelines (Brock *et al.* 2012).
- See additional resources under Step 1.

26. See also http://www.unesco-ioc-marinesp.be/spatial_management_practice/australia_great_barrier_reef.
27. See http://www.pc.gc.ca/progs/amnc-nmca/cnamnc-cnnmca/gwaiihaanas/index_e.asp.

Step 3

Determine whether the impacts on biodiversity from climate change (Step 2) can be mitigated by MPAs or MPA networks

Overview

Steps 3 and 4 will generate a tool to help managers assess the cumulative impacts of climate change and other human impacts on vulnerable biodiversity traits, with the purpose of helping to design an MPA network that might diminish that vulnerability. Managers can use the product of Step 2 and add information to assess the degree to which the habitats vulnerable to climate change impacts can be lessened by MPAs or MPA networks. By constructing a threat assessment model (e.g., the vulnerability of organisms and habitats to anticipated climate change), it may become clear whether MPAs or MPA networks can improve resilience. For example, habitats may be less vulnerable to climate change impacts if they are less subject to pressures such as bottom trawling, bottom tending gear, cable laying, anchoring, and other human disturbances. Similarly, organisms may be less vulnerable to climate change impacts if they are not subject to fishing pressure.

Method

- During the construction of the matrix of habitat types for MPA network planning, consider the likelihood for and degree to which the parameters would be affected by climate change. Refer to Annex 1 of the Guidelines (Brock *et al.* 2012), a high-level overview of the physical (atmospheric and oceanographic) properties that are projected to change over the coming decades—including the direction, magnitude and spatial extent of the changes, as well as an indication of the level of uncertainty.
- Topic specialists can use Annex 1 to estimate the timescale over which climate change is expected to impact the species or habitat of interest and trigger a re-evaluation of MPA management, including the area's boundaries.
- Summarize the vulnerability of each habitat type to different climate change pressures (refer to Annex 2 of the Guidelines [Brock *et al.* 2012]).
- Develop criteria to assess whether MPAs are an appropriate management measure to adapt to climate change-related impacts. For example: Do MPAs help reduce the impacts of climate change-induced stressors on this habitat type? (High, Medium, and Low probability of response success).
- Apply the criteria and present the results in a matrix format.

Practical considerations

- Consider holding an experts' workshop (or reaching out to the scientists convened in earlier steps of this process) to develop the matrix of habitat types and their likely responses to climate change impacts at the appropriate geographic scale (e.g., regional, site-specific) as well as formulate criteria for assessing whether an MPA is an appropriate management measure for adaptation to climate change-related impacts.

Products

- A matrix of habitat types and their likely responses to climate change impacts (e.g., adapt Annex 2 of the Guidelines to show habitat types).

Resources

- Table A1.3 from Annex 1 of the Guidelines (Brock *et al.* 2012); and
- See additional resources under Step 1.

Step 4

Assuming MPAs or MPA networks can mitigate the impacts from climate change identified in Step 3, topical specialists should predict the spatial/timescale over which their subject is expected to respond and trigger a re-evaluation of the MPA boundaries, or design the MPA or MPA network to be robust to these changes

Overview

Annex 1 of the Guidelines (Brock *et al.* 2012) will help planners and managers estimate the timescale over which the species or habitat of interest is expected to respond to climate change impacts and trigger a re-evaluation of the MPA boundaries, or design the MPA or MPA network to be robust to these changes. Once an MPA network has been established, monitoring data should be used to adaptively manage these sites, including making any needed changes to boundaries in order to address changing habitats within the network.

Method

- Develop a matrix of candidate MPA sites for each habitat type, based on initial MPA network planning, illustrating the sites' vulnerability to human use and climate change stressors (e.g., a cumulative impact analysis). This requires spatial information on human uses that may pose threats to specific sites under consideration.
- Develop diversity indices (of species' richness or community composition) that an MPA network should aim to conserve in the context of climate change, including variation across a seascape and within habitat types.
- MPA network planners should use the Convention on Biological Diversity network properties to guide network planning.[28]
- Clearly define the spatial scale of the MPA network design.
- MPA network plans will need to be adapted based on climate change impacts on habitat types. For example, as the coverage of different habitat types shifts with climate change, the representation of these habitats within a network may need to change.
- Determine the degree to which MPAs can help reduce cumulative impacts, including climate change, to each candidate site and present the results in a matrix format (High, Medium, Low probability of response success).
- Use the information generated above to set priorities for designing the MPA network to best lessen the vulnerability of biodiversity traits in a changing climate.

Practical considerations

- This step focuses on integrating response to climate change impacts with other MPA network design criteria. Stakeholders will need to be engaged in setting priorities for the MPA network and educated about the different objectives for the network, including potential trade-offs.
- Given the complexity of this process, managers should explore decision support tools to help guide expert and stakeholder engagement.

Products

- A matrix that identifies specific sites that encompass habitat areas under consideration as potential MPAs. It would identify their vulnerability to a wide range of impacts, including anthropogenic and climate change impacts, to help managers set priorities for protection.

Resources

- Table A1.3 from Annex 1 of the Guidelines (Brock *et al.* 2012) and see additional resources under Step 1.

28. See http://www.cbd.int/marine/doc/azores-brochure-en.pdf.

Photo: Parks Canada

Table of Potential Costs and Levels of Effort Common to All Guidelines

Requirement	Cost	Level of Effort
Step 1:		
Literature review	Low	Low
Meeting of regional science experts to identify Step 1 information and gaps in scientific information	Moderate	Moderate
Local (MPA-level) science workshops (possibly including interviews with fishermen/divers) to identify Step 1 information and gaps in scientific information	Moderate	Moderate
GIS expertise during workshops/meetings to collect remote sensing data and generate maps	Moderate	Moderate
Step 2:		
Literature review and/or data acquisition	Low/Moderate	Low/Moderate
Assessment/modeling workshops	Moderate	Moderate
GIS expertise	Moderate	Moderate
Local meetings to assess vulnerability of various traits to climate change impacts	Moderate	Moderate
Step 3:		
Apply climate models	Moderate	Moderate
Gap analysis	Low	Low
Decisions about whether MPAs are the most appropriate tool to address climate change impacts on particular traits	Low	Low
Step 4:		
Meetings with MPA managers/planners and scientific experts to determine management response	Moderate	Moderate
Model or matrix refinement with technical experts	Moderate	Moderate
Bilateral or trilateral negotiations to ensure network effectiveness	Moderate	Moderate
Monitoring	High	High

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Commission for Environmental Cooperation
393, rue St-Jacques Ouest, bureau 200
Montréal (Québec) Canada H2Y 1N9
t 514 350-4300 f 514 350-4314
info@cec.org / www.cec.org