current
THE JOURNAL OF MARINE EDUCATION
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THE NATIONAL MARINE PROTECTED AREAS CENTER

special issue focused on

NETWORKS OF MARINE PROTECTED AREAS

"... to make known the world of water, both fresh and salt."

THE NATIONAL MARINE EDUCATORS ASSOCIATION brings together those interested in the study and enjoyment of the world of water. Affiliated with the National Science Teachers Association, NMEA includes professionals with backgrounds in education, science, business, government, museums, aquariums, and marine research, among others. Members receive *Current: The Journal of Marine Education, NMEA News,* and discounts at annual conferences. Membership information is available from: NMEA, P.O. Box 1470, Ocean Springs, MS 39566-1470; Phone: (228) 701-1770; Fax: (228) 701-1771; email: johnette@imms.org, or visit our website online at **www.marine-ed.org/.**

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CURRENT LOG *Increasing impacts on the world's oceans and Great Lakes, caused by development, pollution, overfishing, and natural events, strain the health of our coastal and marine ecosystems. Some of these impacts can include decreased or damaged fish populations, loss of wetlands and other coastal habitats, bleached corals, threatened or endangered species, or resulting social and economic impacts. Marine protected areas, or MPAs, are one type of ocean management tool that, when used effectively, help protect and restore our oceans. They may also protect historic artifacts such as shipwrecks that could otherwise be damaged by handling or theft.*

Sometimes a single MPA is not sufficient in size or scope to protect all of the resources that reside within its boundaries. Therefore, a network of MPAs—a grouping of smaller MPAs protecting different habitats at various locations within the larger ecosystem—may be required. This issue of Current *focuses on networks of MPAs, and includes articles written by authors who have had extensive experience in MPA network design, management, and research. The activities and additional resources at the end of the articles will help you bring the concept of MPAs and networks of MPAs directly into your classroom.*

The National Marine Protected Areas Center facilitates the effective use of science, technology, training, and information in the planning, management, and evaluation of the nation's system of marine protected areas. The MPA Center works in partnership with federal, state, tribal and local governments, tribes, and stakeholders to develop and implement a science-based, comprehensive national system of MPAs.

We encourage you to regularly visit our website, www.mpa.gov, to learn more about MPAs.

KARA SCHWENKE *is the Communications and Outreach Coordinator for the National Marine Protected Areas Center. Her work at the MPA Center focuses on communicating the benefits of MPAs and a national system of MPAs to the public. She is the editor of the MPA Center's quarterly e-newsletter,* MPA Connections, *as well as the content editor for the MPA Center's website, www.mpa.gov. Prior to her work with NOAA, Kara was an outreach and communications specialist for both the North Carolina Division of Marine Fisheries, and the Maryland Department of the Environment. Kara received B.S. degrees in Biology and Environmental Science from Salisbury University, and an M.S. in Zoology from North Carolina State University.*

LAUREN WENZEL *has been working for the National Marine Protected Areas Center for the past seven years to build a national system of marine protected areas (MPAs). As the National System Coordinator, Lauren works with federal, state, territorial, tribal, and local MPA programs in the U.S. on issues of common national and regional concern, such as climate change. The national system also supports participating MPA sites through training and technical assistance. She has a strong interest in land/sea interactions and, before joining NOAA, worked on watershed planning to restore Chesapeake Bay. Lauren has a B.A. in English and Government from Oberlin College, and an M.S. from the University of Michigan in Natural Resources Planning.*

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This special issue of Current: The Journal of Marine Education *is sponsored by the National Marine Protected Areas Center.*

Welcome Letter from Dr. Jane Lubchenco

Dear *Current* Readers:

Healthy oceans are important to all of us. To protect and restore our oceans, and ensure that they can continue to contribute to our economy and vibrant coastal communities, President Obama is establishing a national ocean policy that will provide a framework for effectively managing the diverse uses of our oceans and coasts through an ecosystem-based approach. This special edition of *Current*, sponsored by NOAA's National Marine Protected Areas Center, illustrates how marine protected areas (MPAs) and networks can serve as an effective tool for conserving marine resources.

Marine protected areas, or MPAs, have been used for over a century to conserve our nation's oceans, coasts, and Great Lakes resources. In the United States, more than 1,600 MPAs have been created by federal, state, and local governments, spanning a wide range of marine habitats. Each has its own conservation objectives, which range from conserving important habitats and preserving sunken historic vessels to protecting fish spawning grounds important to commercial and recreational fisheries. In some instances, a single MPA may not be large enough in size and scope to adequately protect the marine resources within its boundaries. Many marine species live in various habitats throughout their life cycle, and some migrate huge distances. For a single MPA to protect all of those habitats, it would have to be very large, which isn't always practical or desirable. Networks—a series of smaller MPAs connected by the movement of juveniles or adults—are an effective alternative, especially when they protect different habitats within the larger ecosystem. These networks can effectively conserve marine resources because they can protect multiple stages of an organism's life cycle. NOAA is helping support MPA networks through the development of the national system of MPAs, which works across all levels of government to support common conservation objectives and address management challenges, like climate change impacts, that extend beyond the boundaries of a single MPA.

As a marine educator, you play an important role in helping these conservation efforts. By introducing a world of water that is a mystery to most, you instill a sense of appreciation and wonder in our marine resources. That enthusiasm will continue, as those you teach become stewards of our environment.

This issue of *Current* explores the many types of MPA networks, including ecological networks designed to protect species and habitats, as well as institutional networks to strengthen MPA programs and establish partnerships among different nations (see ***Why are Ecological Networks of Marine Protected Areas Important?*** and ***Institutional Networks of Marine Protected Areas—Connecting People to Protect Places***). While we often think of MPAs as useful tools for conserving important habitats like coral reefs and kelp forests, MPAs also are being created in the open ocean to protect highly mobile species like whales and tuna (see ***Pelagic Reserves for Marine Top Predators: How Big and How Many?***). Lastly, threats such as ocean acidification and climate change are already changing marine ecosystems. Can MPAs play a role in providing some protection against such threats (see ***New Stresses, New Strategies: Managing Marine Protected Areas in an Age of Global Environmental Change***)?

I thank you for your dedication and interest in not only helping to conserve our nation's important natural and cultural marine resources, but your passion for inspiring our children to do the same.

Sincerely,

Dr. Jane Lubchenco
Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator

PHOTO CREDIT

Courtesy of NOAA

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Networks of Marine Protected Areas: What are they and Why are they Needed?

By Kara Schwenke, Lauren Wenzel, and Katya Wowk

Marine protected areas, or MPAs, are one type of ocean management *tool that, when used effectively, help ensure healthy oceans. They may also protect historic artifacts such as shipwrecks that could otherwise be damaged by handling or theft. Sometimes, however, a single MPA is not sufficient in size or scope to protect all of the resources that reside within its boundaries. Therefore, a network of MPAs—a grouping of smaller MPAs protecting different habitats at various locations within the larger ecosystem—may be required.*

Increasing impacts on the world's oceans from coastal and offshore development, overfishing, a changing climate and increased levels of carbon dioxide, natural events, and other sources are straining the health of marine ecosystems and the Great Lakes. Impacts to these intricately balanced environments include declining fish populations, degradation of coral reefs and other vital habitats, threats to rare or endangered species, and loss of artifacts and resources that represent the diverse cultural heritage of the United States. The effects of these losses are significant and jeopardize the social and economic fabric of the nation.

In the United States and around the world, marine protected areas (MPAs) are increasingly recognized as an important and promising management tool for reducing or preventing some of these impacts. An MPA is any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources inside that area (Executive Order 13158, May 2000). In practice, MPAs are areas with specific geographic boundaries where natural and/or cultural resources are given greater protection than in the surrounding waters. In the United States, more than 1,600 MPAs span a range of marine habitats, including the open ocean, coastal areas, intertidal zones, estuaries, and the Great Lakes.

U.S. MPAs may be created by over 100 different local, state, territorial, tribal, or federal authorities. The level of protection provided by these MPAs ranges from fully protected marine reserves, where all extractive uses are prohibited, to those allowing multiple uses, including fishing. Nearly all U.S. MPAs are multiple use and allow public access and fishing.

MPAs have been well documented as successful conservation tools. However, when used alone, individual MPAs may not be sufficient in size or scope, or provide adequate protection to the marine organisms that reside within them. Recent attention has been given to the importance and benefits of networks of MPAs—a set of MPAs within a region or ecosystem that act cooperatively and synergistically (Agardy 2005). Because existing and emerging threats, particularly those posed by climate change and ocean acidification, have the potential to significantly affect marine resources, networks of MPAs are a key tool for restoring and sustaining the health of our nation's oceans and Great Lakes.

Northern Elephant Seals (*Mirounga angustirostris*) have migratory paths that span thousands of miles and cross international boundaries on land and sea.

BENEFITS OF NETWORKS OF MPAs

Ecosystems function at different scales and change over time. Effectively designed networks of MPAs have the ability to account for such temporal and spatial changes because they connect ecosystem components within and between networks. Numerous other ecological benefits are associated with networks of MPAs. For example, most marine fishes and invertebrates live in various habitats throughout their life cycle. If different types of habitats are represented in individual MPAs within the network, not only will different species be protected, but entire life stages of organisms could be protected. From a fisheries perspective, networks of MPAs can positively affect the biomass, abundance, size, and diversity of some species within the MPAs, and those impacts can extend outside the boundaries of MPAs (IUCN-WCPA 2008). These concepts are given further consideration in a subsequent article in this issue (see *Why are Ecological Networks of Marine Protected Areas Important?*).

Further, networks of MPAs are valuable management tools in the face of wide-scale threats like climate change, as changing conditions that negatively impact habitats or populations in one MPA may not affect other MPAs within the network. Thus, MPAs are a useful tool in an adaptation strategy to climate change, potentially providing refugia for key species. For more information about MPAs and climate change, see the article *New Stresses, New Strategies: Managing Marine Protected Areas in an Age of Global Environmental Change* in this issue.

Networks of MPAs can provide social benefits by helping to resolve and manage conflicts in the marine environment (PISCO 2007). Institutional MPA networks can be formed to facilitate learning and coordination of administration and planning by linking people and institutions involved in MPAs into a coordinated and holistic initiative. The institutional networks provide a means for individual MPA stakeholders or communities to coordinate with each other to share experiences and to enhance each other's efforts in managing their respective MPAs (White et al. 2006)

Economically, MPA networks can increase the pool of available funding and staff to address issues and problems common to more than one site. Within networks, common issues and concerns can be easily identified. Pooled resources and a shared agenda for action promote swift and effective responses to shared problems. Collective and collaborative actions in outreach and education can mobilize support for individual sites and the concept of marine protected areas generally. The shared experiences of site managers and agency administrators can be critical to avoiding duplication of effort when a site in the network encounters situations that others have already resolved.

DESIGN CRITERIA FOR EFFECTIVE MPA NETWORKS

An effective network of MPAs is not just several individual MPAs grouped together. Major ecological design criteria (IUCN-WCPA 2008) to consider when designing MPA networks, which may be of less or more importance depending on the aims of a network, include:

Representativeness: MPA networks should represent the range of marine and coastal biological diversity (from genes to ecosystems) and the associated oceanographic environment within the given area. All ecosystems and habitats within the region should be represented in the MPA network. To ensure this, MPA managers must assess the type and distribution of habitats and identify representative and unique habitats that should be protected in order to address conservation goals. For example, if a network of MPAs is intended to protect nurseries and feeding grounds of blue crabs, then MPA managers must consider all habitats that blue crabs use throughout their entire life cycle (creeks, rivers, estuaries, bays, different depths within the water column, different salinities, etc.).

Replication: MPA networks are most effective when each habitat type is represented in more than one MPA. Ideally, all habitats in each region should be replicated within the network and distributed spatially throughout the network. This replication helps provide "stepping-stones" for species that are dispersed within the network, and also provides a safeguard against unexpected habitat loss or population collapse.

Blue crabs (*Callinectes sapidus*) have a complex life cycle where they utilize different ecosystems during their lifetime. Juvenile crabs like the one shown above live in shallow estuarine waters where they use underwater seagrasses as a refuge.

Connectivity: Connectivity describes the extent to which populations in different parts of a species' range are linked by the exchange of eggs, larvae, juveniles, or adults. MPA network design should recognize the patterns of connectivity within and among ecosystems (e.g., ecological linkages among coral reefs, seagrasses, and mangroves). An MPA network that is intended to protect a mobile species must consider all the habitats the species uses in its entire life cycle.

Resilience: MPA networks must be designed to maintain ecosystems' natural states and to absorb shocks, particularly in the face of large-scale and long-term changes such as climate change. Representativeness and resilience are closely related criteria: if a range of habitats are represented in a network of MPAs, then that network may be able to accommodate changes in species distribution, salinity differences, temperature differences, and other ecosystem dynamics that are often associated with global warming.

Permanence: MPA networks must provide long-term protection to effectively conserve diversity and replenish resources. Though some biological changes may occur relatively quickly after implementation, the full benefits of MPAs and networks of MPAs may not be noticeable for years. The long-term protection of MPAs, especially no-take MPAs, may positively affect fish species and fisheries because research has proven that biomass, abundance, size, and diversity of some fish species are all increased within an MPA. Larger fishes produce more eggs, resulting in increased offspring that can repopulate the MPA and provide recruits and spillover into non-protected areas.

Size and shape: Individual MPA units within the network must be of sufficient size to minimize adverse impacts from activities outside the protected area. Typically, larger MPAs provide benefits to a wider diversity of species than smaller MPAs because they encompass the adult movement ranges and larval dispersal distances of more species. However, smaller MPAs have their benefits too, including the fact that they are easier to enforce, and the benefits (both ecological and economical) may accrue faster in a smaller MPA. The shape of an MPA should consider the onshore-offshore or life-stage shifts of the species it is trying to protect, but should also allow for clear marking of boundaries for both users and enforcement personnel.

CHALLENGES IN DESIGNING AND MANAGING EFFECTIVE NETWORKS OF MPAS

Though the above design criteria will likely enhance the effectiveness of MPA networks, managing human activities in ocean areas presents many challenges. MPA networks require the same resources and conditions needed to ensure the success of other management measures: management and technical capacity, sufficient funding, enforcement and public support, and recognition of the value of ocean resources, which leads to the political will to address these challenges (CBD 2007). Embedding the creation of MPAs and networks of MPAs within a broader governance system of integrated ocean and coastal management can help to address these problems and enhance effectiveness, which becomes even more important when one considers the transboundary nature of many ocean and coastal issues.

EXAMPLES OF MPA NETWORKS

Institutional Networks

Ecosystems and the species living within them do not adhere to political or jurisdictional boundaries. Therefore, they require cooperative management among state, regions, nations, and jurisdictions (WCPA/IUCN 2007). An institutional network of MPAs is a network of people managing the components of individual MPAs and promoting the network's viability and longevity. Institutional MPA networks can be formed to facilitate collaboration, learning, resource sharing and MPA planning, and can help lay the groundwork for stronger political commitments to marine conservation and more effective cooperation across jurisdictional boundaries. The U.S. participates in the North American Marine Protected Areas Network (NAMPAN), the Pacific Islands Marine Protected Areas Community (PIMPAC), and the Caribbean Marine Protected Area Management Network and Forum (CaMPAM). These networks are further described in the article *Institutional Networks of Marine Protected Areas—Connecting People to Protect Places,* found later in this issue.

Ecological Networks

Ecological networks of MPAs are a set of discrete MPAs within a region that are connected through dispersal of reproductive stages (eggs, larvae, spores, etc.) or movement of juveniles and adults. A common component of ecological networks are marine reserves, commonly referred to as no-take areas, or areas in the ocean that are fully protected from activities that remove animals and plants or alter habitats. Because reserves

Institutional Networks of MPAs can facilitate information sharing and provide opportunities for people to share their vision and goals for MPAs.

do not allow any extractive activities, they can protect multiple habitats and species, and provide insurance against catastrophes. An example of an ecological network in the U.S. is the Marine Life Protection Act in California, which is a series of MPAs, including marine reserves in state waters off the coast of California. The nearshore California case study is described in more detail in the article *Why are Ecological Networks of Marine Protected Areas Important?*, while the article *Pelagic Reserves for Marine Top Predators: How Big and How Many?* describes considerations for designing offshore MPAs to protect wider-ranging species such as whales and turtles.

Fitting Networks of MPAs into the Big Picture

MPA networks cannot solve broad ocean management conflicts or issues alone. However, MPA networks can contribute to conserving our ocean's health if they are implemented within larger frameworks of adaptive, ecosystem-based management, integrated ocean governance, and coastal management.

Coastal and marine spatial planning (CMSP) is a comprehensive, adaptive, integrated, ecosystem-based, and transparent spatial planning process, based on science, for analyzing current and anticipated uses of ocean, coastal, and Great Lakes areas. CMSP has recently gained momentum in the U.S. with President Obama's creation of an Ocean Policy Task Force (OPTF). In December 2009, the Task Force released the *Interim Framework for Effective Coastal and Marine Spatial Planning* for public comment, with a final Framework expected in spring 2010. The Interim Framework outlines the scope and breadth of ocean planning in the United States and identifies MPAs as a management and conservation tool that, when used comprehensively with other tools, can facilitate compatible uses and preserve critical ecosystem services to meet economic, environmental, security, and social objectives.

For CMSP to be successful, it must be based on clear, broad-based goals that define the desired outcomes to be achieved.

Networks of MPAs are just one component of a comprehensive ecosystem-based management approach.

MPAs and MPA networks can contribute to two of the national goals defined in the Interim Framework:

- to support sustainable, safe, secure, efficient, and productive uses of the ocean, our coasts, and the Great Lakes; and
- to protect, maintain, and restore the nation's ocean, coastal, and Great Lakes resources and ensure resilient ecosystems.

MPA networks can provide ecological, financial, and social benefits. Institutional networks can strengthen the facilitation of knowledge, resources, and communications. Ecological networks of MPAs can help conserve critical life stages of marine species, protect groups of spawning adult fish, and act as an insurance policy against global threats such as climate change. With continued research and increased education and awareness about the benefits of MPAs and networks of MPAs, these tools can continue to conserve our nation's ocean and coastal resources for future generations.

KARA SCHWENKE (see bio on page 1)

LAUREN WENZEL (see bio on page 1)

KATYA WOWK is the Policy Specialist at NOAA's National Marine Protected Areas Center, where she focuses on developing and implementing strategies that respond to and influence decisions made by federal agencies, in the context of the National System of MPAs. She has a special interest in enhancing marine ecological resilience in light of climate change impacts and ocean acidification, and conducting analyses of the policies that are needed to support such resilience. Katya is a Ph.D. Candidate in Marine Policy at the University of Delaware, and holds an M.S. from Columbia University in Environmental Science and Policy.

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Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). (2007). *The Science of Marine Reserves* (Second Edition, United States Version). www.piscoweb.org. 22 pgs.

WCPA/IUCN. (2007). *Establishing Networks of Marine Protected Areas: A Guide for Developing National and Regional Capacity for Building MPA Networks*. Non-technical summary report.

White, A.T., P.M. Alino, and A.T. Meneses. (2006). *Creating and Managing Marine Protected Areas in the Philippines*. Fisheries Improved for Sustainable Harvest Project, Coastal Conservation and Education Foundation, Inc. and University of the Philippines Marine Science Institute, Cebu City: Philippines, 83 p.

FOR MORE RESOURCES

Framework for the National System of Marine Protected Areas of the United States of America, National Marine Protected Areas Center, November 2008: **http://mpa.gov/pdf/national-system/finalframework_full.pdf**

Interim Framework for Effective Coastal and Marine Spatial Planning, Interagency Ocean Policy Task Force, December 9, 2009: **http://www.whitehouse.gov/sites/default/files/microsites/091209-Interim-CMSP-Framework-Task-Force.pdf**

PHOTO CREDITS

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Page 7: Courtesy of the National MPA Center

In Focus: The National System of Marine Protected Areas of the U.S.

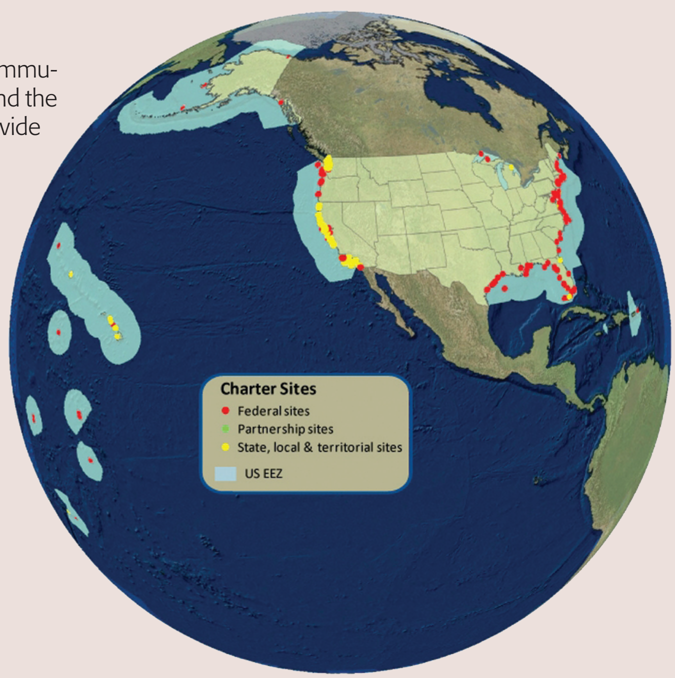
The United States has developed a national system of marine protected areas (MPAs) to advance the conservation and sustainable use of the nation's vital natural and cultural marine resources.

The national system was established to leverage the capabilities of over 100 existing federal, state, territorial, and tribal MPA programs that span the nation's coastal, marine, and Great Lakes regions in order to strengthen natural and cultural marine resource conservation. The national system of MPAs enhances place-based protection of important U.S. marine resources by providing new opportunities for regional and national cooperation; supports the national economy by helping to sustain fisheries and maintain healthy marine ecosystems for tourism and recreation businesses; and promotes public participation in MPA planning, decision-making by improving access to scientific and public policy information.

The goals of the national system are to conserve and manage:

- **Natural heritage** – the nation's biological communities, habitats, ecosystems, and processes, and the ecological services, values, and uses they provide
- **Cultural heritage** – cultural resources that reflect the nation's maritime history and traditional cultural connections to the sea, as well as the uses and values they provide
- **Sustainable production** – the nation's renewable living resources and their habitats (including, but not limited to, spawning, mating, and nursery grounds and areas established to minimize bycatch of species) and the social, cultural, and economic values and services they provide

The national system became a reality in 2009 with the publication of the *Framework for the National System of Marine Protected Areas of the United States of America,* and the acceptance of the charter group (225 sites) of existing federal, state, and territorial MPAs into this voluntary partnership. Future nomination processes will be held annually, and the system will expand over time.



Location of charter members of the National System of Marine Protected Areas (April 2009).

Activity: Working Together with Sherman and the National System of Marine Protected Areas

FOCUS

Marine protected areas, the national system of MPAs, stakeholder participation

GRADE LEVEL

6-8 (Humanities, language arts, life science)

FOCUS QUESTIONS

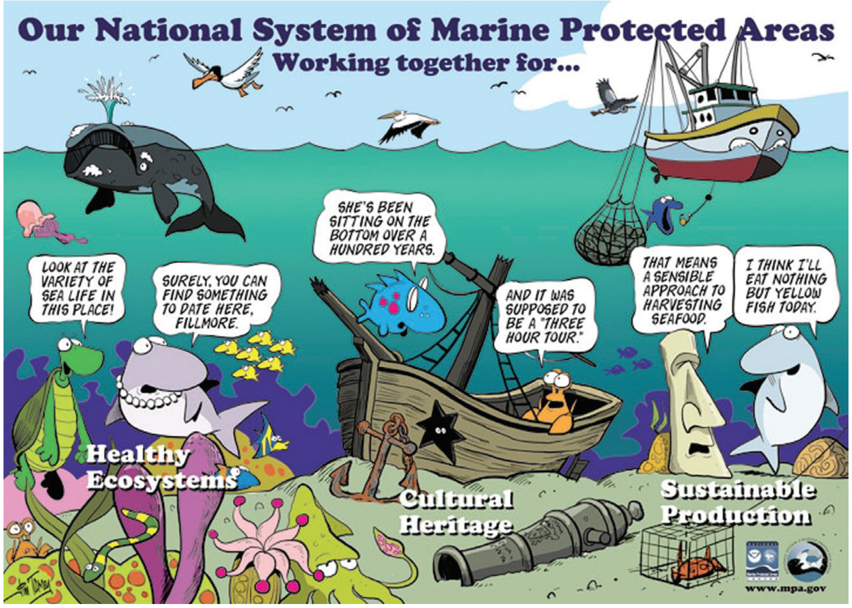
- What is a marine protected area, and why is the national system of MPAs important?
- Why is stakeholder participation important in MPA design and management?

MATERIALS

- Copies of *Joining the National System of MPAs: Frequently Asked Questions* and *Benefits of the National System of MPAs* fact sheets
- Copies of the Lesson Vocabulary Guide (see "For More Resources" to access these)

AUDIO/VISUAL MATERIALS

Computer with internet access to view *Protecting Our Planet* video



BACKGROUND INFORMATION

Somewhere in a lagoon near the fictional Kapupu Island in the North Pacific, a great white shark named Sherman is planning his next meal. And, thanks to the healthy and sustainable marine environment he calls home, Sherman has a delicious variety from which to choose. According to Jim Toomey, the creator of *Sherman's Lagoon*, the cartoon features "a dimwitted shark named Sherman, his sea turtle sidekick, and an assortment of other coral reef critters who team up to battle the encroachment of civilization on their remote tropical paradise." If "Sherman's Lagoon" were real, chances are it would be a marine protected area (MPA).

WHAT IS A MARINE PROTECTED AREA?

Some people interpret marine protected areas to mean areas closed to all human activities. Others interpret them as special areas set aside for recreation, much like national parks. In reality, "marine protected areas" are defined areas where natural and/or cultural resources are given greater protection than the surrounding waters. In the United States, nearly all MPAs have multiple uses and allow for activities such as fishing, diving, and beach use.

The official federal definition of an MPA is: "any area of the marine environment that has been reserved by federal, state, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein," Executive Order 13158 (May 2000). U.S. MPAs span a range of habitats, including the open ocean, coastal areas, intertidal zones, estuaries, and the Great Lakes. They also vary widely in purpose, legal authorities, agencies, management approaches, level of protection, and restrictions on human uses. Some common examples of MPAs in the U.S. include: National Marine Sanctuaries, National Parks and Seashores, National Wildlife Refuges, fisheries closures, and state counterparts to these programs.

WHAT IS A SYSTEM OF MPAs?

A system of MPAs is a set of areas connected by their shared conservation goals, managing agency (such as a federal or state organization), or other common interests. A system of MPAs is not necessarily confined to a geographic region, but can span regions and ecosystems, like the U.S. National System of MPAs. The national system of MPAs is the group of MPA sites established and managed by federal, state, tribal, and/or local governments. Although individual MPA sites and programs are managed independently, together these MPAs work to achieve common conservation goals. Collectively, these sites help conserve the nation's natural and cultural marine heritage and represent its diverse ecosystems and resources.

WHY THE NATIONAL SYSTEM OF MARINE PROTECTED AREAS?

MPAs offer valuable natural and cultural assets through greater protection than the surrounding waters. They include areas such as deep-water habitats, estuaries, intertidal zones, fish spawning grounds, and the Great Lakes. The U.S. has more than 1,600 MPAs, established by federal, state, territorial, and local governments to protect ecosystems, conserve cultural resources, and sustain fisheries.

The national system of MPAs:

- enhances protection of U.S. marine resources by providing new opportunities for MPA programs to collaborate and cooperate;
- supports the national economy by helping to sustain fisheries and maintain healthy marine ecosystems for tourism and recreation businesses; and
- promotes public participation in MPA decision-making by improving access to scientific and public policy information.

Building awareness of MPAs as valuable tools for conserving the nation's natural and cultural marine resources encourages a global view of a healthy planet for future generations. Use this series of lessons to enhance your team's curriculum in science, social studies, math, and English/language arts; or use them as an interdisciplinary project for more than one of these disciplines. The lesson plans center on the Jim Toomey poster and utilize internet resources to encourage critical thinking, and give students tools for understanding and evaluating authentic source materials.

Use these key words to make the connection to your state or district standards: balance, culture, diversity, economic impact, ecosystem, estuary, food chain, food web, habitat, life cycle, marine environments, marine organisms, maritime history, ocean resources, population, predator, prey.

GETTING STARTED

Engage

Show the poster and ask for student observations (for information on how to receive a copy of the poster for your classroom, see "For More Information" at the end of this lesson). Ask if any have seen these cartoon characters elsewhere, and if so, what the general essence of the cartoon's message is. That theme of "battling the encroachment of civilization on a remote tropical paradise" is extended to marine protected areas in general. For more about the characters, visit the Sherman's Lagoon website at http://slagoon.com/charactr/charactr.html.

Elicit the main idea and supporting details of the poster.

- Help students determine that the information on the poster is segmented into three vignettes.
- Have students use dictionaries if needed to create operational definitions of **healthy ecosystems, cultural heritage**, and **sustainable production**. You might use the MPA Glossary, found in the "For More Resources" section of this lesson, as background on how the MPA Center defines these terms.
- Ask volunteers to read the speech bubbles in each vignette and solicit other volunteers to tell what they think each conversation means. Work with students to connect their responses to their operational definitions of healthy ecosystems, cultural heritage, and sustainable production.

Explore

Take students to the National Marine Protected Areas Center website (http://mpa.gov/) to begin their exploration of the national system of marine protected areas. Introduce this site as a collaboration of two government agencies—the National Oceanic and Atmospheric Administration and the Department of the Interior. Tell them to treat the information at a site (such as this) as nonfiction text. Have volunteers tell how the home page is structured and what kind of information they can find or navigate to.

Explain

Show students the short video *Protecting Our Planet* (http://mpa.gov/resources/multimedia/; approximately 10 minutes). Before viewing, ensure students know the definitions of these terms: comprehensive system, management tool, network, and stake-holders. Use the lesson vocabulary guide found in the "For More Resources" section. Ask the students to take notes while viewing the video, and facilitate a discussion using the students' observations and below key points from the video.

- Contrast the amount of ocean that is protected compared to the total amount of ocean on earth with the amount of land that is protected compared to the total amount of land on earth.
- How the ocean may be affected by the shift of the population to within 60 miles of a coastline.
- Examples of the kinds of ecosystems they saw in the video and habitats that are protected.

- How an MPA is similar to a state or national park or refuge on land, and how those similarities are beneficial to a marine ecosystem.
- How having a national network of MPAs can be beneficial to individual MPAs.
- Why stakeholders have to be involved in establishing MPAs.
- The number of people worldwide who depend on the ocean for food.
- That marine protected areas are one of many tools for conserving resources, ensuring sustainable production, and protecting the long-term health of our ocean's ecosystems.

Elaborate

Take students to the tab "about MPAs" (http://mpa.gov/aboutmpas/). First have them discern how this page is structured for navigation, with summary text in the main column and links on the left that correlate to sections in the summary.

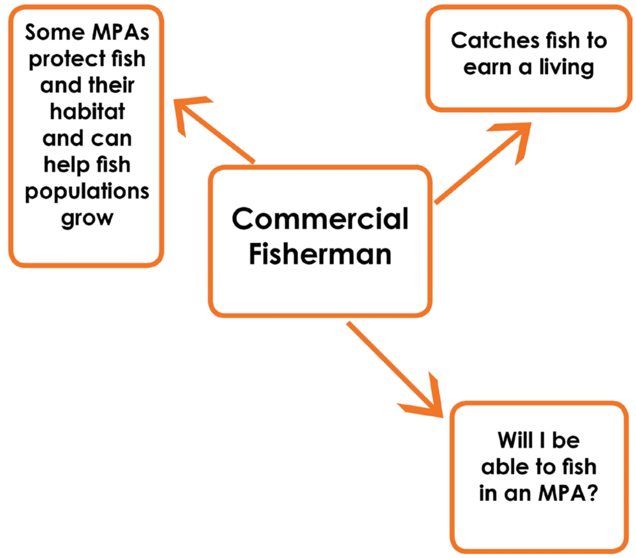
Under the "national system" tab, point out to students the three goals of the national system of MPAs—natural heritage, cultural heritage, and sustainable production. Ask volunteers to read the three points. Then elicit from students how to set up the description of the goals as a simple graphic organizer, such as a Venn diagram or word web, telling the main idea and supporting details. Refer back to the operational definitions of healthy ecosystems, cultural heritage, and sustainable production they created for the poster and make comparisons.

Ask students about the purpose of FAQs or Frequently Asked Questions. Download *Joining the National System of MPAs: Frequently Asked Questions* and give small groups black and white copies of them. Then click on *Benefits of the National System of MPAs* and download the fact sheet. Have black and white copies available of pages 1-3 of the fact sheet for small groups. Students should use markers to highlight key descriptive phrases in each section. You might direct them to the lesson vocabulary guide to ensure students understand terms such as: stewardship, partnership, outreach, connectivity, and transparent. Students might also benefit from *The National System of MPAs: Snapshot of the United States* fact sheet (see "For More Resources" section).

Evaluate

Brainstorm an operational definition of "stakeholder" and lead the class in a discussion of which individuals or groups might be interested in the designation and management of an MPA. Help focus the class by providing examples such as a commercial fisherman or an environmentalist. Have students create a list of stakeholders and discuss how each stakeholder is interested and invested in MPAs. Have small groups choose a stakeholder and create a web diagram illustrating the characteristics, interests, and concerns of that particular stakeholder. Groups might use the *Benefits of the National System of MPAs* fact sheet and the FAQs as background.

Example:



Have each group use their web diagram to present their stakeholder's situation to the class and their position on whether the stakeholder might be supportive, undecided, or against MPAs.

CLOSING

Ask the class why is it important to include stakeholders in MPA management decisions? Follow with a group discussion.

THE BRIDGE CONNECTION

Click on "ocean science" in the navigation bar on the left, then "human activities," then "Oceans for Life Resources Library": **www.vims.edu/bridge/**

OCEAN LITERACY: ESSENTIAL PRINCIPLES OF OCEAN SCIENCES GRADES K-12

- Essential Principal 1: Fundamental concept h
- Essential Principal 3: Fundamental concepts e,h
- Essential Principal 5: Fundamental concepts c,d,e,f,i
- Essential Principal 6: Fundamental concepts a,b,c,d,g

FOR MORE INFORMATION

To receive a copy of the National System Poster for your classroom or if you have any questions, please contact: Kara Schwenke, Communications Coordinator, National Marine Protected Areas Center, NOAA, 1305 East West Highway N/ORM, Silver Spring, MD, 20910 (email: Kara.schwenke@noaa.gov; phone: 301-563-1162).

Lesson developed by: Judy Elgin Jensen, Research & Conceptualization (phone: 813-659-4561; www.concorddata.com)

FOR MORE RESOURCES

MPA Glossary: **http://mpa.gov/resources/glossary/**

Lesson Vocabulary Guide:
http://mpa.gov/resources/education

Joining the National System of MPAs: Frequently Asked Questions fact sheet: **http://mpa.gov/resources/faqs/**

Benefits of the National System of MPAs fact sheet:
http://mpa.gov/nationalsystem/#benefits

The National System of MPAs: Snapshot of the United States fact sheet: **www.mpa.gov/pdf/national-system/nat_sys_snapshot.pdf**

NOAA Coral Reef Conservation Program educational resources website: **http://coralreef.noaa.gov/education/educators/resourcecd/lessonplans/**

NOAA's Office of National Marine Sanctuaries (offers a variety of educational materials and activities):
http://sanctuaries.noaa.gov/education/welcome.html

NOAAs National Estuarine Research Reserves Program education website (offers extensive lessons and activities for all ages): **http://estuaries.gov/**

SeaWeb (non-profit) is the creator of *Trade-Off!* (a board game that illustrates the importance of stakeholder participation in marine protected area management decisions; and see below): **www.seaweb.org**

Article about the importance of community involvement in MPAs: **http://www.uri.edu/news/releases/?id=5231**

PHOTO CREDIT

Page 11: Courtesy of Daria Siciliano, SeaWeb

TRADE-OFF!—THE MARINE SPATIAL PLANNING BOARD GAME

SeaWeb and the University of Maryland's Integration and Application Network created *Trade-Off!*, an interactive board game that allows players to understand the concepts of marine spatial planning (MSP) and the perspectives and interests of different ocean users. An opportunity to learn through play!

Trade-Off! puts players into the role of different coastal stakeholders—from natural resource managers, commercial fishermen, scientists, developers, to elected officials and others—to negotiate uses and activities in a coastal community and shape a management plan.

Trade-Off! has been used to stimulate group discussion and learning in formal (schools, universities) and informal (aquaria, museums) educational settings where the audience is interested in learning about these concepts through a fun, interactive visual tool.

The *Trade-Off!* board illustrates a stretch of a temperate coast with a variety of habitats (rocky coast, sandy beaches, wetland, seagrass meadows, open ocean, sloping uplands, etc.). Players impersonate coastal stakeholders in the financial, social, and environmental sectors who negotiate and place activities of interest, thus shaping a spatial management plan.

Trade-Off! is a fun and interactive way to gain insight into the goals and perspectives of various ocean users through participation in discussions and negotiations in ocean zoning and MSP, which emphasizes the importance of fulfilling ecological, social, and economic objectives.

To learn more about the *Trade-Off!* board game, please visit SeaWeb's website at http://www.seaweb.org/resources/ebm/SeaWebsEBMCommunicationsProject.php#tradeoff.

To request a trial with the beta version of the game for your classroom, or for any questions regarding *Trade-Off!*, please contact SeaWeb at ebm@seaweb.org. Please check SeaWeb's website regularly for updates of when a new and expanded version of the game will be available for wider use and distribution.

Institutional Networks of Marine Protected Areas—Connecting People to Protect Places

By Georgina Bustamante, Meghan Gombos, Hans Hermann, Karen Schmidt, and Alessandra Vanzella-Khouri

MPA NETWORKS ARE NETWORKS OF BOTH PEOPLE AND PLACES. *While we often focus first on networks as connected places that provide enhanced ecological values, the connections among people—MPA managers, stakeholders, and communities—are perhaps even more important. These linkages among people provide opportunities to establish a common vision and goals for important marine areas, share information and resources, enhance capacity building, and work together to address problems beyond the borders of individual MPAs.*

The U.S. is participating in three regional MPA networks—the North American MPA Network, the Caribbean Marine Protected Areas Management Network and Forum, and the Pacific Island MPA Community. Each of these networks has a unique focus, and provides an opportunity to address the challenges of MPA management at a regional scale. While all of these networks were established to address common threats to marine management, including overfishing, habitat loss, and pollution, they adopt regionally specific approaches to these problems.

NORTH AMERICAN MPA NETWORK

Canada, Mexico, and the United States have each made a commitment to move toward an ecosystem approach to the management and conservation of their marine resources. An ecosystem approach is precautionary in nature and has the health of the whole marine ecosystem as its primary objective. Although the three nations have taken significant steps in developing federal legislation to protect the marine environment, effective implementation of an ecosystem approach requires transboundary cooperation and complementary conservation and management actions.

In response to this challenge, the North American Marine Protected Areas Network (NAMPAN) was born in November 1999 under the auspices of the newly created North American Free Trade Agreement's Commission on Environmental Cooperation (CEC). Its goal was to enhance and strengthen the conservation of biodiversity in critical marine habitats throughout North America by establishing a functional system of ecologically based MPA networks that cross political borders and depend on broad cooperation.

By creating a system of marine protected areas spanning national, state/provincial, and local jurisdictions, the benefits of protected areas can be greatly increased. From its inception it was clear that the NAMPAN needed to function both as a network of *places* and as a network of *institutions and people*.

NAMPAN aims to:

- implement complementary, integrated conservation efforts;
- increase collaboration and development of cross-cutting conservation initiatives;
- enhance collaboration to address common challenges to marine biodiversity; and
- increase regional, national, and international capacity to conserve critical marine and coastal habitats, sharing of data, information, new technologies, and management strategies.

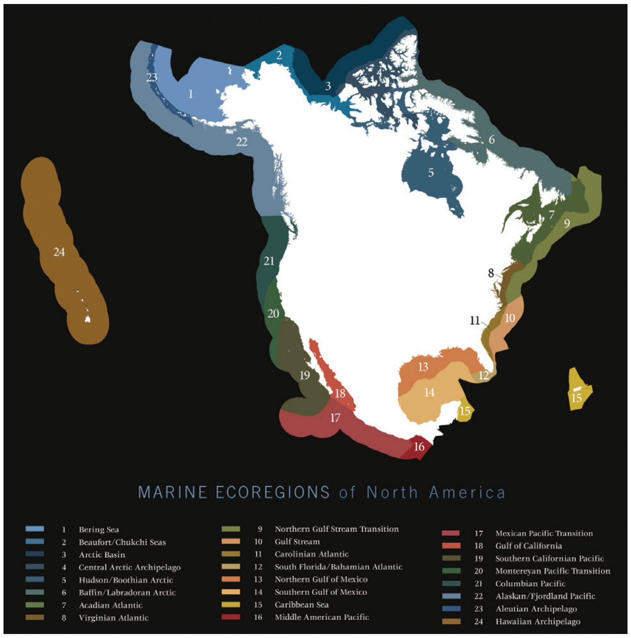


Figure 1. NAMPAN's 24 unique eco-regions.

Defining the biogeography and extent of North America's marine ecosystems was a key prerequisite to implementing an integrated ecosystem approach. To fill that gap, NAMPAN developed a nested system of 24 unique eco-regions to classify our coasts and oceans (Figure 1). These eco-regions transcend national boundaries and provide a meaningful ecologically based framework for a continental network of MPAs. Each of these eco-regions represents a large body of water differentiated by oceanographic features and geographically distinct assemblages of species that interact ecologically in ways that are critical for their long-term persistence.

As the next step in this strategic approach, the CEC convened leading ecologists to identify 14 ecologically significant regions (both terrestrial and marine), based on their ecological value at the continental scale, level of threats to their integrity and functioning, and the potential opportunities for tri-national cooperation. Of these 14 regions, the Baja California to Bering Sea Region (B2B) connects the marine realms of the three countries and offers concrete opportunities for collaboration.

SETTING CONTINENTAL CONSERVATION PRIORITIES

Moving from the large scale-strategic priorities down to the scale where conservation action and collaboration was immediately required, NAMPAN identified 28 Priority Conservation Areas (PCAs) in the B2B region. Those PCAs were selected because of their ecological significance (e.g., species diversity, ecosystem services, migratory species, etc.); level and type of threats (e.g., unsustainable fisheries, pollution); and opportunities for conservation (e.g., existing conservation initiatives, indigenous groups).

The B2B Priority Conservation Areas established a regional blueprint for marine conservation on which to base a network of critical and important marine habitats. To make the network operational, several MPAs (within the PCAs) were selected by the three countries to test the NAMPAN principles.

TAKING THE PULSE OF MPAs IN THE BAJA CALIFORNIA TO BERING SEA REGION

NAMPAN's first focus in the B2B region was assessing the environmental condition and trends of MPAs within the network. Healthy habitats and functioning ecosystems are critical components of an effective network. To assess the environmental conditions, NAMPAN developed a Condition Assessment Scorecard, distilling large amounts of complex technical and traditional/local ecological knowledge about MPA conditions for a few selected MPAs within the B2B region.

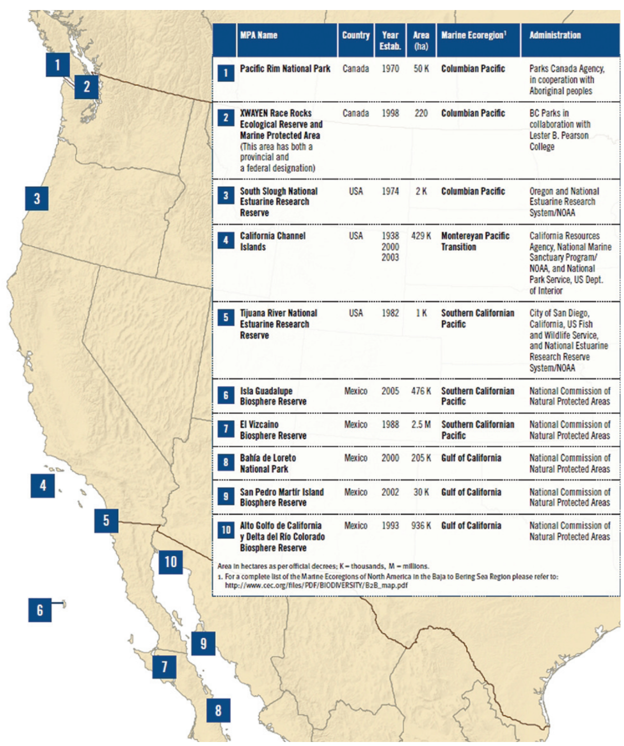
Ecological scorecards are a tool for understanding ecosystem health, contributing to the improvement of science and evidence-based ocean stewardship, and increasing public involvement in MPA management. This assessment tool, applied broadly, could further support systematic environmental monitoring for improved regional and continental scale conservation strategies.

For the pilot project, NAMPAN selected 10 MPAs in the B2B region representing a diverse array of biogeographical settings (Figure 2). While the public perceives healthy oceans as highly desirable and supports public policies to sustain them, people generally lack an adequate understanding of the conditions needed to evaluate ocean health. Ecological scorecards act as a bridge between the technical and scientific communities and the public at large, including their elected and appointed leaders.

As a basis for this pilot, CEC, in collaboration with MPA experts from the three countries, developed a series of 14 standard questions about MPA water, habitat, living resources, and human activities to describe environmental health (Table 1). This approach was adapted from the condition reports created by NOAA's National Marine Sanctuaries.

For each question, a standard scoring grid was developed, related to conditions and trends. Conditions for each ecosystem element addressed by the questions were defined on a five-point scale, ranging from superior (best) to critical (worst). Trends in conditions were likewise defined in five categories, ranging from rapidly improving to rapidly diminishing (likely to reach a different state in five years) and stable (unlikely to change beyond normal variation).

With the successful implementation of the condition scorecard approach in the B2B, the CEC Council of ministers has encouraged NAMPAN to consider expanding its strategic approach



	MPA Name	Country	Year Estab.	Area (ha)	Marine Ecoregion[1]	Administration
1	**Pacific Rim National Park**	Canada	1970	50 K	**Columbian Pacific**	Parks Canada Agency, in cooperation with Aboriginal peoples
2	**XWAYEN Race Rocks Ecological Reserve and Marine Protected Area** (This area has both a provincial and a federal designation)	Canada	1998	220	**Columbian Pacific**	BC Parks in collaboration with Lester B. Pearson College
3	**South Slough National Estuarine Research Reserve**	USA	1974	2 K	**Columbian Pacific**	Oregon and National Estuarine Research System/NOAA
4	**California Channel Islands**	USA	1938 2000 2003	429 K	**Montereyan Pacific Transition**	California Resources Agency, National Marine Sanctuary Program/ NOAA, and National Park Service, US Dept. of Interior
5	**Tijuana River National Estuarine Research Reserve**	USA	1982	1 K	**Southern Californian Pacific**	City of San Diego, California, US Fish and Wildlife Service, and National Estuarine Research Reserve System/NOAA
6	**Isla Guadalupe Biosphere Reserve**	Mexico	2005	476 K	**Southern Californian Pacific**	National Commission of Natural Protected Areas
7	**El Vizcaino Biosphere Reserve**	Mexico	1988	2.5 M	**Southern Californian Pacific**	National Commission of Natural Protected Areas
8	**Bahía de Loreto National Park**	Mexico	2000	205 K	**Gulf of California**	National Commission of Natural Protected Areas
9	**San Pedro Martír Island Biosphere Reserve**	Mexico	2002	30 K	**Gulf of California**	National Commission of Natural Protected Areas
10	**Alto Golfo de California y Delta del Río Colorado Biosphere Reserve**	Mexico	1993	936 K	**Gulf of California**	National Commission of Natural Protected Areas

Area in hectares as per official decrees; K = thousands, M = millions.

1. For a complete list of the Marine Ecoregions of North America in the Baja to Bering Sea Region please refer to: http://www.cec.org/files/PDF/BIODIVERSITY/B2B_map.pdf

Figure 2. The 10 diverse MPAs in the B2B region selected for the pilot project.

North American Marine Protected Area Network Ecological Scorecard Questions		
Question 1	(Water/Stressors)	To what extent are specific or multiple stressors, including changing watershed, oceanographic and atmospheric conditions, affecting water quality, quality, distribution, and timing, and how are the stressors changing?
Question 2	(Water/Nutrient Effects)	To what extent are nutrient loads affecting ecosystem health, and how are they changing?
Question 3	(Water/Human Health)	To what extent do water conditions pose risks to human health, and how are they changing?
Question 4	(Water/Human Activities)	To what extent do human activities influence water quality and inputs, and how are they changing?
Question 5	(Habitat/Extent and Distribution)	To what extent does habitat alteration, including the extent and distribution of major habitat types, affect ecosystem health, and how is it changing?
Question 6	(Habitat/Contaminants)	To what extent do contaminants in habitats affect living resources or water quality, and how are they changing?
Question 7	(Habitat/Human Activities)	To what extent do human activities influence habitat extent and quality, and how are they changing?
Question 8	(Living Resources/Biodiversity)	What is the status of biodiversity, and how is it changing?
Question 9	(Living Resources/Extracted Species)	What is the status of extracted species, and how is it changing?
Question 10	(Living Resources/Alien Species)	What is the status of alien species, and how is it changing?
Question 11	(Living Resources/Keystone and Indicator Species)	What is the status and condition of keystone and indicator species, and how is it changing?
Question 12	(Living Resources/Focal Species)	What is the status and condition of focal species, and how is it changing?
Question 13	(Living Resources/Species of Common Concern)	What is the status and condition of species of common conservation concern?
Question 14	(Living Resources/Human Activities)	To what extent do human activities influence living resource quality, and how are they changing?

Table 1. NAMPAN ecological scorecard questions

to embrace the Atlantic, the Gulf of Mexico, and Caribbean. In 2010, NAMPAN will initiate activities in the Atlantic to the Caribbean region of Canada, Mexico, and the United States, implementing a methodology that applies current, science-driven network planning criteria as developed in CBD processes and elsewhere (such as connectivity and replication), to help North American MPA agencies collectively and individually consider how to plan an Atlantic to Caribbean network that builds on nationally identified, existing and candidate MPA sites, and in a manner that takes into account climate change and the adaptive capacity of marine ecosystems.

PACIFIC ISLAND MPA COMMUNITY

The Pacific Islands Marine Protected Areas Community (PIMPAC) is a collaboration of MPA managers; non-governmental organizations; local communities; federal, state, and territorial agencies; and other stakeholders working together to collectively enhance the effective use and management of MPAs in the U.S. Pacific Islands (Hawaii, American Samoa, the Commonwealth of the Northern Mariana Islands, and Guam) and Freely Associated States (Federated States of Micronesia, Marshall Islands and Palau) (Figure 3).

PIMPAC began in 2005 as a pilot program, funded by the NOAA Coral Reef Conservation Program and the Department of Interior's Office of Insular affairs, to identify and address the unique set of challenges faced by MPA managers in the region. These challenges include limitations in human and financial resources, physical isolation which restricts the sharing of successful management approaches, and building on traditional management approaches while adapting to modern technology and practices.

Figure 4. Participants at the PIMPAC August 2005 workshop discuss information on ways to increase the effectiveness of MPA management in the Pacific.

To overcome these challenges, more than 45 MPA leaders from around the region met in August 2005 to explore ways of working together to increase the effectiveness of MPA management in the Pacific (Figure 4). The participants shared a common vision for a regional social network that would strengthen their individual and collective MPA efforts. They committed to work together through the development of a regional "Pacific Islands MPA Community," an idea which also served as the original name of the group. Participants agreed that the aim of PIMPAC would be to provide a continuous forum for: 1) training and technical support, 2) learning exchanges, 3) partnership building, and 4) information sharing.

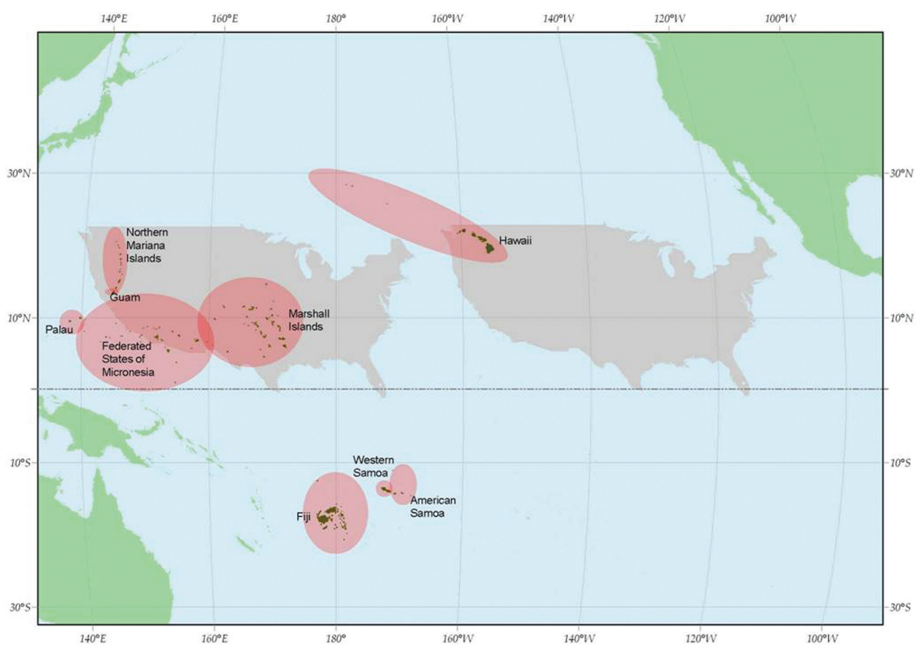


Figure 3. The Pacific Islands Marine Protected Areas Community (PIMPAC). This map illustrates the size of this region, relative to the continental U.S.

Since 2006, PIMPAC has been evolving and adapting to fulfill its regional aims and meet local partner needs. A three-year strategic plan was developed to focus PIMPAC support and provide clear understanding on the approach of its efforts. During the first few years, PIMPAC's training efforts have been focused on MPA management planning and community/stakeholder engagement to build a foundation for future technical support on other priority topics such as monitoring effectiveness (social and biological) and enforcement. PIMPAC also has focused efforts on sharing information among partners, offering learning exchanges, and supporting youth involvement in MPA efforts. PIMPAC has evolved to support national and regional efforts to develop ecological networks of effective MPAs. For example, the Micronesia Challenge has committed to protecting 30% of the nearshore marine resources across Micronesia by 2020. In addition, the Two Samoas Initiative is working to establish a linked network of MPAs in American Samoa and the independent state of Samoa (formerly Western Samoa).

Building on these efforts, PIMPAC has recently expanded its scope to include management of land adjacent to marine protected areas to take a holistic "ridge to reef" approach to management, prompting the revision of the group's name to Pacific Islands Managed and Protected Areas Community. Plans for the next few years involve better integration of terrestrial managers into PIMPAC activities, as well as institutionalizing training into regional academic programs to provide long-term capacity building opportunities.

PIMPAC's mission is to provide continuous opportunities for the sharing of information, expertise, practice, and experience to develop and strengthen area-based management capacity throughout the Pacific Islands region. The community provides support to land and marine area-based management efforts in the region to support a holistic approach to management from ridge to reef. It provides support to "on the ground" resource managers.

As a social network, PIMPAC carries out four main activities to fulfill its mission. They are:

- **Training and technical assistance:** By facilitating an environment where area-based managers can express needs and identify gaps in capacity, PIMPAC can strategically support these managers by developing, adapting, and/or providing access to tools that will be most effective to the regional audience. Additionally, PIMPAC can offer a suite of skills to fill in capacity gaps and build logical steps for management effectiveness that meet regional standards for ecosystem-based management.
- **Learning exchanges:** As a mechanism to communicate lessons learned and stories between islands, learning exchanges both provide inspiration and examples of solutions to those facing similar challenges.
- **Partnership building:** With a long-term vision, PIMPAC aims to institutionalize training so that access to skill building is ongoing. This supports the management effectiveness of current managers, as well as providing opportunities for future managers to gain experience in resource management. As a coordination mechanism among regional partners, PIMPAC can leverage complimentary programs to get more accomplished with less funding.
- **Communications/information sharing:** PIMPAC can act both as a forum for sharing successes and lessons learned within the community and as a voice for leadership to help shape "support programs" and increase political will.

PIMPAC coordinates the above stated activities to support area-based management efforts on the ground. PIMPAC has progressed through informal, transparent approaches where all partners can provide input, comments, and be part of shaping the direction of PIMPAC activities. Strategic plans have been developed through stakeholder input, and the identified activities are implemented via PIMPAC Coordinators and partners. Coordination provides a common vision among partners and the ability to leverage resources (technical and financial) to the region for area-based management.

CARIBBEAN MPA MANAGEMENT NETWORK AND FORUM

The Wider Caribbean region includes 38 continental and island countries and territories that posses coasts along the tropical and subtropical waters of the Caribbean Sea and the Gulf of Mexico. The region extends from South Florida south to French Guyana, including the Bahamas, Mexico, Central America, the Greater and Lesser Antilles, and Colombia, Venezuela, Trinidad and Tobago, Suriname and Guyana; and occupies a Coastal Biogeographic Province with nine marine eco-regions (Sullivan,

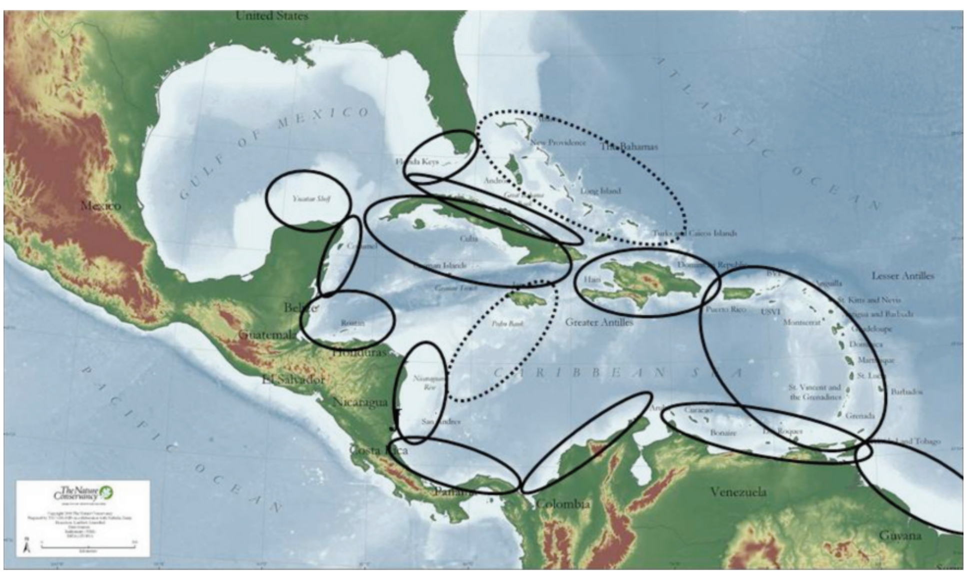


Figure 5. Map of the Wider Caribbean and its tentative units of biological connectivity of marine populations (ovals with dotted lines depict less documented or potential additional divisions).

Sealey, and Bustamante 1999; Spalding 2008) (Figure 5). Recent studies on larval dispersal (Paris et al. 2006; Cowen et al. 2006; Bustamante and Paris 2008; Steneck et al. 2009) suggest that the eco-regional scenario of the Caribbean is more complex and divided than previously estimated.

The expansion of the fisheries industry in the region has exceeded the capacity of many fish stocks to replenish naturally. As a result, the abundance of fishes, lobster, and conch have declined in some areas to a point where species such as Nassau grouper and queen conch, have become "commercially extinct" (not abundant enough to be fished). In addition to excessive fishing, major impacts to ecosystems include poorly managed coastal development, inadequate tourism practices, and land-based and marine pollution, leading to loss of critical marine habitats such as coral reefs, seagrasses, and mangroves. In additional, coral reef diseases and bleaching have had a significant impact in reef environments.

As more information becomes available on the success and failures of managing individual MPAs and the linkages among populations of marine species within the entire Caribbean, the need for MPAs to coordinate their management and function as a network to achieve their conservation goals is increasingly clear. Individually, MPAs can provide some local benefits, but working as a network they can better protect critical areas for species reproduction, nesting, and growth. Thus, most Caribbean countries and conservation organizations aim to establish effective networks of MPAs with multiple uses (e.g., conservation, recreation, and fishing). So far, only a few national MPA systems are being developed by some countries, and eco-regionally based networks are still in the minds of conservation scientists and planners.

In order to expedite the process of ecologically based MPA networks and coordination of transboundary national systems, human communication is critical. Social and professional networks of marine resource practitioners are essential to facilitate learning, coordination, and efficient use of resources. In this context, the Caribbean Program of the United Nations Environment Programme (UNEP-CEP) created the Caribbean Marine Protected Area Management Network and Forum (CaMPAM) in 1997 to "enhance marine and coastal area management in the Wider Caribbean Region through sharing and collaboration to strengthen national and regional systems of existing and future marine and coastal protected areas." Since then, based on priority needs identified by managers, CaMPAM has developed a series of communication and capacity building tools to disseminate best management practices and foster collaboration in MPAs across the Wider Caribbean. CaMPAM has evolved since its inception, adjusting to emerging needs, as well as adapting to new science and information to improve management effectiveness.

CaMPAM's program to build institutional capacity of MPAs includes the following activities:

Figure 6. The Florida Keys National Marine Sanctuary law enforcement officers show the participants of the 2006 Training of Trainers Regional Course for MPA Managers their enforcement practices.

- Regional Training of Trainers Program (Figure 6);
- exchange visits of fishers and MPA managers to disseminate best practices;
- small grants to promote responsible fishing and alternative livelihoods for fishers in or around MPAs;
- a regional MPA database; and
- information dissemination via CaMPAM Forum, a list-serve, publications, and workshops.

The unique geopolitical and cultural setting of the Wider Caribbean region has many characteristics that may facilitate a regional approach to managing marine resources. These include:

- **Similar climate and oceanographic conditions:** Tropical marine currents that enter the Caribbean Sea from the Atlantic Ocean flow to exit along the Florida coast as the Gulf Stream.
- **One marine biogeographic province with several eco-regions:** Although the region shares most marine species populations (fishes, invertebrates, turtles, plants, mammals), the province is probably divided into distinct eco-regions or units of connectivity of marine populations due to the existence of the gyres and meandering currents that retain oceanic larvae (see Figure 5 on page 16).
- **Coastal tourism-based economies:** In most countries, coastal tourism is the dominant industry.
- **Few languages:** English and Spanish are the dominant languages, although French, Dutch, Creole, and Papiamento are also spoken in some islands.

- **Similar historical and cultural heritage:** Colonialism and slave trade shaped the formation of the Caribbean culture in the 16th-18th centuries.

- **Geographic closeness:** Thirty-eight states and territories within a 1.2 million km^2 basin.

- **A regional intergovernmental agreement for coastal and marine resources:** The Cartagena Convention and its Protocols (1981) provide a legal framework to address issues for the protection and sustainable development of the marine environment. All countries of the region currently participate in this program.

Despite these favorable conditions, many challenges to effective transboundary and eco-regional scale management of marine resources remain. National and sub-regional systems of MPAs that include no-take areas and areas of responsible fishing, in combination with other management tools (for the coastal and upland areas), may contribute to maximize the marine environmental services of the Wider Caribbean in the 21st century.

CONCLUSION

The experiences of these three regional MPA networks illustrate the benefits of establishing institutional connections between MPA managers and programs—developing a common conservation vision; sharing the best MPA science and management tools; and collaborating on shared problems. The International Union for the Conservation of Nature (IUCN) has noted the critical importance of economic, social, and governance considerations in establishing effective networks. By establishing coordination mechanisms, institutional networks can promote and facilitate stronger political commitments to marine conservation and more effective cooperation across jurisdictional boundaries.

ALESSANDRA VANZELLA-KHOURI is the Programme Officer for the Caribbean Environment Programme (CEP) of the United Nations Environment Programme (UNEP) in Kingston, Jamaica. She promotes and coordinates activities with governments and organizations in the Wider Caribbean on biodiversity conservation; sustainable use of coastal and marine resources; marine protected areas; coral reef management; threatened and endangered species; and other related issues. She is a member of the World Commission on Protected Areas and has been a founder and an active member of the Caribbean Marine Protected Areas Network and Forum (CaMPAM). She also functions as the responsible officer within the UNEP-CEP Secretariat for the regional biodiversity treaty on Specially Protected Areas and Wildlife for the Wider Caribbean (SPAW Protocol).

HANS HERRMANN is a marine ecologist with over 25 years experience in the field of biodiversity conservation and natural resource policy. As Head of the Biodiversity Conservation Program of the North American Commission for Environmental Cooperation (CEC), he led the development and implementation of a North American cooperation strategy for the conservation of biodiversity. Before joining the CEC, he was the General Director of Pronatura Nacional for eight years, the largest non-governmental organization devoted to the conservation of biodiversity in Mexico. Prior to that, Mr. Herrmann was the Science Director at the Scientific Research Center of Quintana Roo (CIQRO) in the Yucatan Peninsula where his main responsibility was the management and coordination of scientific research in the Sian Ka'an Biosphere Reserve.

KAREN SCHMIDT joined CEC's Biodiversity Conservation program in the summer of 2000, where she has coordinated the implementation of numerous trilateral initiatives and publications. She has a background in Education from McGill University and the National Autonomous University of Mexico (UNAM), with majors in psychology and capacity building and training. Prior to joining the CEC, she was involved in the evaluation of teacher training programs at the *Instituto Latinoamericano de la Comunicación Educativa* (ILCE). She has written a number of articles for Trio, CEC's newsletter and IC Education. She has been involved in various outreach activities related to mass media and education.

GEORGINA BUSTAMANTE, PH.D., is a marine conservation scientist and coordinator of the Caribbean Marine Protected Area Management Network and Forum (CaMPAM). She graduated as a marine biologist at the University of Havana, Cuba in 1973 and in 1987 received her Doctorate degree in Biological Sciences. She worked for 20 years at the Institute of Oceanology of Cuba as a scientific researcher and consultant on fisheries resource management, coastal development, and mariculture. From 1994 to 2007, she worked as a marine conservation scientist in the Caribbean and Latin American programs of The Nature Conservancy (TNC), an international conservation organization based in the United States. She has coauthored over 30 scientific articles and books.

MEGHAN GOMBOS works for NOAA's Coral Reef Conservation Program and is based in Hawaii. She was involved in the development of the Pacific Islands Marine Protected Areas Community (PIMPAC) six years ago and has co-coordinated the network ever since. She also works regionally with partners in the U.S. Pacific and Freely Associated States on coral conservation related initiatives such as the Micronesia Challenge. Prior to her work at NOAA, she focused her studies and work on international resource management, with a focus on marine protected areas. This work led her to opportunities in Belize, Costa Rica, and Mexico specifically. She has a BS in Marine Biology from the University of New Hampshire and a Masters of Marine Affairs from the University of Rhode Island.

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Why are Ecological Networks of Marine Protected Areas Important?

By Steven Gaines and Satie Airamé

Scientists have long debated the merits of single large or several small (SLOSS) protected areas on land. Larger protected areas can include multiple habitats and large populations of associated species, while several small protected areas may provide protection for an even greater diversity of habitat types and species in a smaller total area. Although smaller protected areas create more borders that, when crossed, put species at risk, safe corridors between separate protected areas may enhance protection by directing movement, such as dispersal, migration, and recolonization, to other protected patches.

In the sea very large marine protected areas (MPAs), such as the Papahānaumokuākea Marine National Monument in the Northwest Hawaiian Islands, can protect a rich diversity of habitats and species (Selkoe et al. 2008). However, the feasibility of creating very large MPAs along most coastlines is limited by the high density of coastal human populations and the multitude and intensity of human activities in the ocean. In such settings, networks of multiple MPAs are a compromise to achieve broad scale conservation benefits for ocean species, while allowing a multitude of uses in the gaps between MPAs. In the ocean, marine animals can disperse and migrate through a liquid medium, which provides fewer barriers than the urban and developed landscapes between terrestrial protected areas. In addition, most marine animals produce young that are microscopic and drift in the plankton. As a result, they can leave the protection of one MPA and disperse to another MPA without being at risk from fisheries while they are in unprotected waters. If designed correctly, networks of MPAs can allow for connections between animal populations in separate MPAs, leading to increased abundance, resilience, and sustainability of targeted marine populations (Almany et al. 2009; Lester et al. 2009; Hamilton et al. in press; Botsford et al. 2001). In addition, where feasible, MPAs should be located in areas with important biological habitats and not based on political or administrative rules, as these actions may limit the overall ecological benefit of the MPA (Monaco et al. 2007).

There are only a few places in the world's ocean where large networks of MPAs exist. The Great Barrier Reef Marine Park in Australia encompasses the largest network of MPAs in the world, while the state of California is completing a network of MPAs within state waters (Osmond et al. 2010). Smaller networks of MPAs are located in New Zealand, where MPAs have been in place for over 30 years, South Africa, the Philippines, and Saint Lucia in the Lesser Antilles, and southern Florida, among others. Scientists have studied these MPAs extensively to learn how they affect marine ecosystems (Halpern and Warner 2002; Halpern 2003; Lester et al. 2009).

WHAT BENEFITS DO MPAs PROVIDE?

Not all types of MPAs provide the same level of protection for habitat and species. Fully protected marine reserves, or "no-take" areas, provide a high level of protection, because they do not allow any type of extractive activity. Other types of MPAs allow some kinds of fishing and other extractive activities, reducing the level of protection afforded by these MPAs. To evaluate the protection provided by MPAs, scientists must take into account the types of activities allowed, the species targeted, and the gear types used in MPAs.

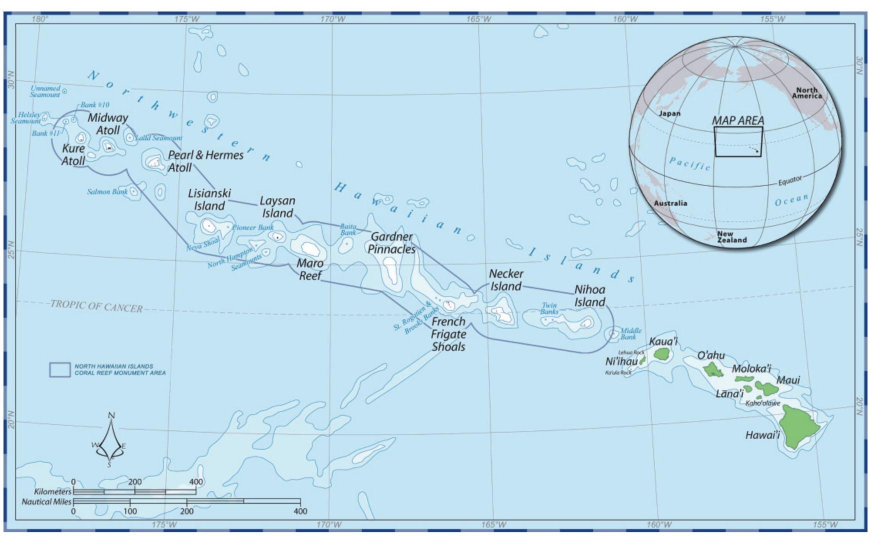

Figure 1. Papahānaumokuākea Marine National Monument, encompassing 140,000 square miles (360,000 km^2) of ocean waters and 10 islands and atolls of the Northwestern Hawaiian Islands, was established on June 15, 2006.

The benefits of highly protected marine reserves that minimize human impacts are well known from over 124 studies conducted in marine reserves worldwide (Lester et al. 2009). On average, biomass (the mass of animals and plants studied) is more than 400% greater, and density (the number of plants and animals in a given area) is 166% greater in marine reserves than outside. Body size also typically increases for fish and invertebrates in marine reserves, and the number of species in the reserve is greater. Marine reserves in both tropical and temperate climates exhibit similar benefits (Lester et al. 2009). It is much harder for scientists to determine the benefits of marine conservation areas and parks that allow limited fishing. Existing data suggest that these limited-take areas may provide much less protection than fully protected marine reserves, depending on the activities that are allowed (Lester and Halpern 2008; Lester et al. 2009).

When MPAs are arranged in a connected network, reproduction that occurs in one MPA can influence the growth of populations in other MPAs. Regular ecological exchange between MPAs in a connected network contributes to the abundance, resilience, and sustainability of regional populations (Murray et al. 1999; Gaines et al. in press). Replication of protection in multiple MPAs in a network also offers reduced risk from localized catastrophes, such as a large storm or oil spill (Allison et al. 2003). Following a catastrophic disturbance, populations in MPAs are more likely to recover quickly if other unaffected MPAs provide a source of young to recolonize the disturbed sites.

These benefits of MPA networks do not come entirely at the expense of fisheries. Each MPA in the network can enhance fishing along its border since fish that cross the boundary are no longer protected. In addition, if MPAs are connected by the dispersal of young, unprotected areas between MPAs also will be seeded by the offspring of adults protected in the network. These fishery benefits can offset some or all of the costs associated with fisheries closures (Plan Development Team 1991; White et al. 2008; Gaines et al. in press).

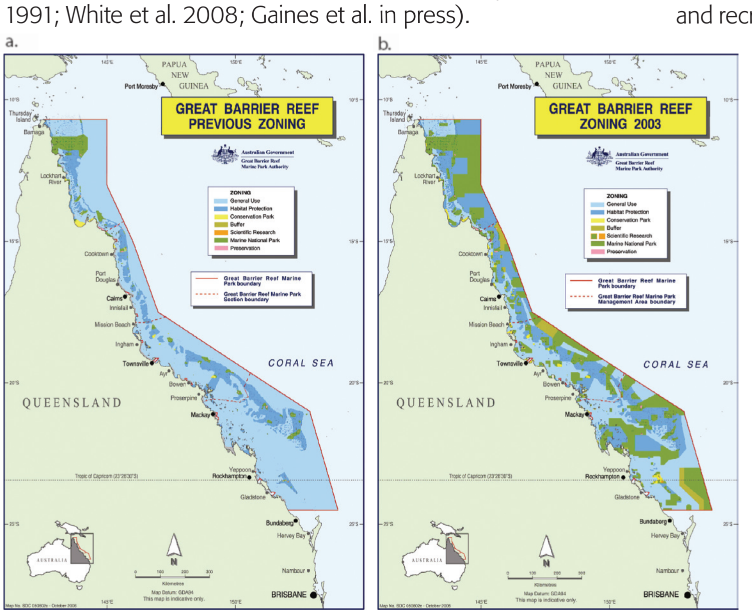

Figure 2. Zoning plans for the Great Barrier Reef Marine Park, Australia. The initial zoning plan (a), implemented in the 1980s, encompassed 4.6% of the Marine Park in no-take areas; while the revised zoning plan (b), implemented in 2004, designated over 33% of the Marine Park in no-take areas to achieve conservation goals.

CASE STUDIES OF ECOLOGICAL MPA NETWORKS

Great Barrier Reef Marine Park, Australia

The Australian federal government established the Great Barrier Reef Marine Park (GBRMP) in 1975, encompassing an area of 133,000 square miles of ocean bordering the northeast side of the country (Fernandes et al. 2005). The GBRMP spans about 2,400 miles along the coast of Queensland, stretching beyond the combined length of the coastlines of the U.S. states of California, Oregon, and Washington. Managers completed the first zoning plans for the GBRMP in the late 1980s, resulting in 4.6% of the GBRMP in "no-take" zones (Figure 2a). Scientists monitored key marine habitats and species in the GBRMP to determine whether or not the zoning plans were successful. In the mid-1990s, park managers determined that ecosystem health and key species continued to decline, and they concluded that the existing network of no-take marine reserves (mostly coral reefs) was not sufficient to protect the full range of biodiversity in the GBRMP. To meet their mandate to conserve the Great Barrier Reef ecosystem, while allowing reasonable use, managers initiated a process to rezone the entire GBRMP in 1999 (Day 2004). The rezoning process focused on objectives of sustaining biological diversity, protecting marine habitats, and protecting and restoring depleted or threatened species. Independent scientific advisers assisted in the development of both a set of biophysical and socioeconomic operational principles to guide the new zoning and to achieve management goals. GBRMP staff developed a comprehensive public process to systematically gather information and feedback from citizens and stakeholders. Information on habitats, species, commercial and recreational uses, and local knowledge was integrated using a range of planning techniques, including computer-based decision support tools, which collectively provided options to balance management goals with user interests (Osmond et al. 2010). Staff incorporated scientific design principles, public input, and the best available information to recommend the most optimum design as the new Zoning Plan (McCook et al. 2010). Ultimately, the new Zoning Plan became law in 2004, including over 33% in no-take zones, while allowing for fishing to continue in other areas of the GBRMP (Figure 2b). An additional 33% is zoned such that the benthic habitat is fully protected, including a prohibition on bottom-trawling.

California's Marine Life Protection Act Initiative

California's Marine Life Protection Act, signed into state law in 1999, requires the state to design and manage a network of marine reserves and other MPAs to protect marine ecosystems and marine natural heritage. In 2004, the California Resources Agency combined state and private funding to launch the Marine Life Protection Initiative, which brought together three groups of volunteer advisors: (1) a Blue Ribbon Task

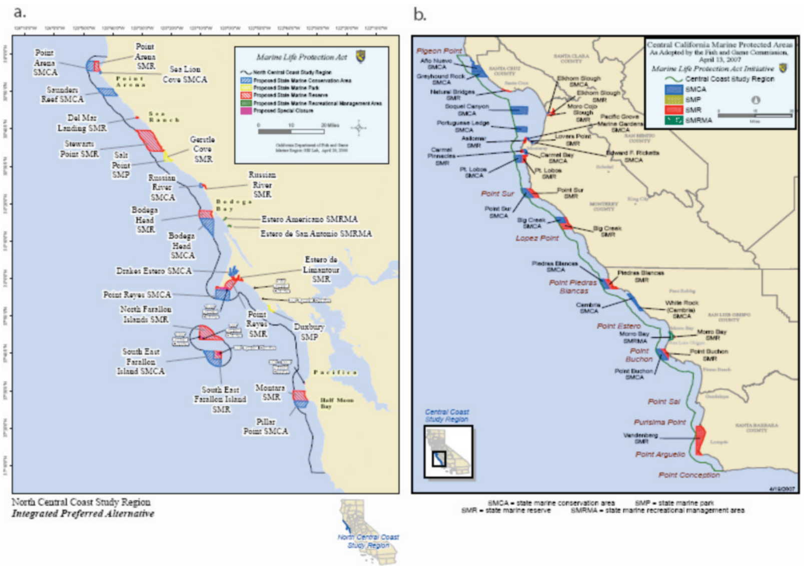

Figure 3. MPA networks for north central (a) and central (b) California under the Marine Life Protection Act. MPAs were established in central California in 2007. MPAs in north central California were adopted by the California Fish and Game Commission and were implemented on April 1, 2010. Red areas are no-take state marine reserves; blue areas are marine conservation areas that allow limited commercial and recreational take; yellow areas are state marine parks that allow limited recreational take; and green areas are state marine recreational management areas where special restrictions apply.

Force of knowledgeable public leaders to guide the process; (2) groups of stakeholders to create different possible designs for MPA networks; and (3) a science advisory team to share information, answer questions, develop guidelines for MPA design, and evaluate proposed MPAs (www.dfg.ca.gov/mlpa). This approach integrates local knowledge of stakeholders with the best available scientific information for planning MPA networks. For planning purposes, the California Resources Agency divided the coast into four regions and San Francisco Bay. To date, networks of MPAs have been designed or implemented in three of the four regions, the process for the fourth region is underway, and the process for San Francisco Bay will begin in 2011. A major challenge for California is that the coastal ocean is adjacent to many large cities and towns, and hundreds of thousands of citizens depend on the ocean for their livelihoods or recreation. Competing uses in California's coastal ocean include: commercial and recreational fishing, diving, sailing, surfing, sunbathing, oil and gas extraction, cooling for power plants, shipping, military training and defense, border patrol, research, and education, among others. In this complex management environment, a network of marine reserves and other protected areas offer an opportunity to conserve marine habitats and species, while allowing the myriad uses in other areas (Klein et al. 2008). Preliminary data from monitoring the initial network of marine reserves in California's Channel Islands indicates that, within just five years, biomass and density of fish and invertebrates targeted by fishermen outside reserves had substantially greater biomass and density inside marine reserves (Hamilton et al. in press).

DESIGN AND MANAGEMENT OF ECOLOGICAL MPA NETWORKS

Collections of multiple MPAs in a network offer great flexibility, because many different configurations offer similar ecological benefits. The science advisory team for California's Marine Life Protection Act Initiative developed a set of guidelines for network design based on syntheses of existing scientific information.

Although a network of several MPAs can be used to capture the diversity of habitats in a region, there are strong conservation benefits from individual MPAs that include a wide range of habitats. By extending from the nearshore to deeper waters and encompassing a variety of habitats, single MPAs can benefit species that use different habitats and, more importantly, accommodate species that move into different habitats as they progress through their life cycle.

Since fish lose the protection of the MPA every time they cross its border into fished waters, the benefits of an individual MPA will depend on how large it is relative to the home range sizes of species of interest (Almany et al. 2009). Home range sizes for different marine species vary widely from just a few meters for some invertebrates and seaweeds to hundreds or thousands of miles for many marine fishes (Figure 4). The appropriate size for an individual MPA will depend on its management goals and availability of marine habitats in the area of interest. For any particular MPA size, some species will be protected within the MPA's boundaries and others will not, because they move too broadly. Affording protection for these more mobile species require other types of management strategies. In California's MPA planning process, the science advisory team recommended setting aside at least nine to 18 square miles and preferably 18 to 36 square miles in an individual MPA to benefit a wide range of species that move tens of miles or less (CDFG 2008).

The amount of each habitat and the total area set aside in MPAs is influenced by the approach to and goals for management. For example, in Australia's Great Barrier Reef Marine Park, each habitat was assigned a target percentage for protection in MPAs (Fernandes et al. 2005). The target percentage varied with the perceived importance of the habitat to species diversity and ecosystem function. In California's Marine Life Protection Act Initiative process, key habitats, such as rocky reefs, kelp forests, and sandy bottoms, were identified in the Act (California Public Resources Code §§ 2850-2863). The science advisory team determined how much of each habitat would be needed to represent 90% of the associated species, and that size is the minimum target for representation of a particular habitat in an individual MPA.

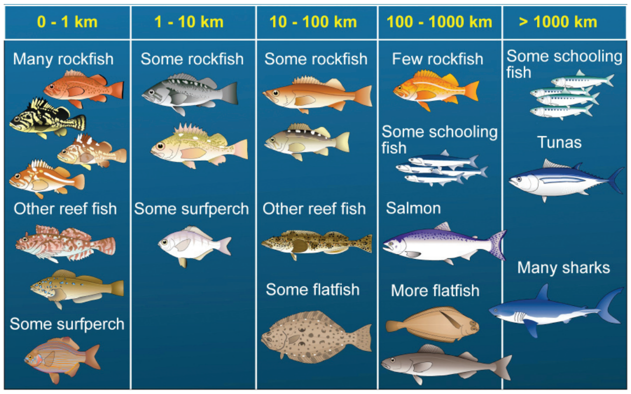

Figure 4. Adult home range sizes for different fish species. Some species will be protected within small MPAs, while many species will travel distances that exceed the boundaries of a single MPA. Strategic design of a network of MPAs can protect a variety of species by including habitats needed during different stages of the life cycle, such as foraging habitats and spawning and nursery grounds.

MPAs in a network must be located close enough to exchange larvae in order to provide mutual benefits. That is, meaningful numbers of the larvae produced in one MPA must settle in other MPAs (Almany et al. 2009). If an MPA is large enough, many larvae produced in that MPA may be retained there, and some may disperse into and settle in fished waters nearby. Seaweeds and some invertebrates have limited dispersal, while other invertebrates and many fish move long distances (tens to hundreds of miles) during the larval stage (Figure 5). To form an ecological network, however, adjacent MPAs must be connected through regular exchange of larvae.

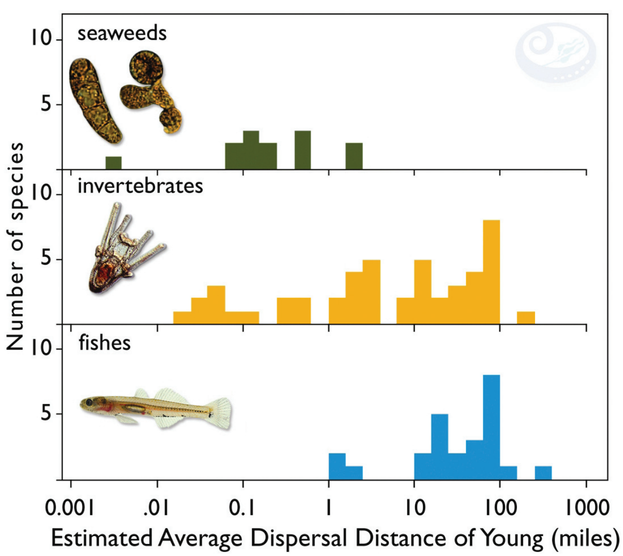

Figure 5. The estimated average distances traveled by young invertebrates (51 species), fishes (26 species), and seaweeds (13 species) prior to settling at their adult homes. Distances are based on genetic analysis of species around the world.

Ecological effects of individual marine reserves are well known and documented in the scientific literature. The wealth of information about marine reserves reduces the need to monitor individual reserves within a network. Less well understood are effects of MPA network design, such as MPA size and spacing, on network function. For example, an MPA network includes MPAs of many different sizes and with many different levels of protection. Do smaller MPAs and those with lower levels of protection contribute in meaningful ways to network function? Do large gaps in protection for a particular habitat type cause discontinuity in coastal populations of fish and invertebrates? Also of interest to scientists is how individual MPAs and networks of MPAs affect opportunities to fish. Based on information about movement and dispersal of marine organisms, scientists hypothesize that MPAs are likely to contribute to fishing through export of young fish and invertebrates. However, these potential consequences are difficult to document, because it is challenging to identify definitively whether a fish that is caught in one location had parents that lived in an MPA. Strategic monitoring of the world's emerging networks of MPAs is needed to answer these management questions.

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SATIE AIRAMÉ, PH.D., is an ecologist and marine policy specialist at UCSB. Both Drs. Gaines and Airamé served as science advisors during public processes to develop networks of MPAs in California's Channel Islands and other California state waters under the Marine Life Protection Act (MLPA) Initiative.

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References available upon request by contacting the National Marine Protected Areas Center at mpainfo@noaa.gov.

PHOTO CREDITS

Page 20: Courtesy of NOAA

Page 21: Courtesy of the Spatial Data Centre, Great Barrier Reef Marine Park Authority (2010)

Page 22: California Department of Fish and Game and Marine Life Protection Act Initiative

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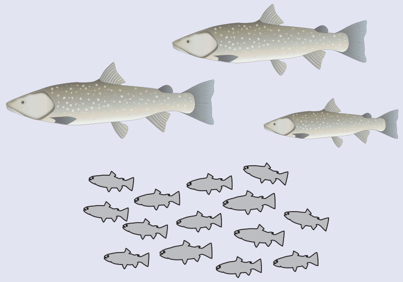
Page 23 (bottom): Data Courtesy of Kinlan and Gaines *Ecology* (2003) and Graphic Courtesy of PISCO (2007)

How Marine Reserves and Networks Protect Ocean Resources

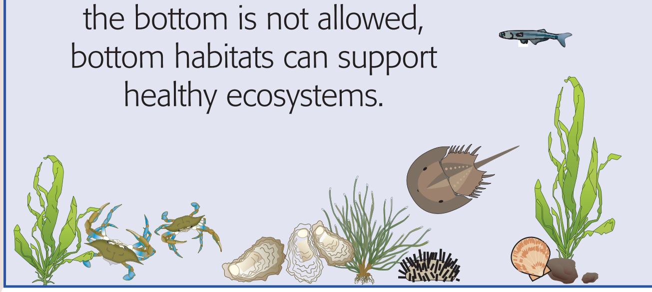
Marine reserves are a type of marine protected area that are fully protected from activities that remove animals and plants or alter habitats.

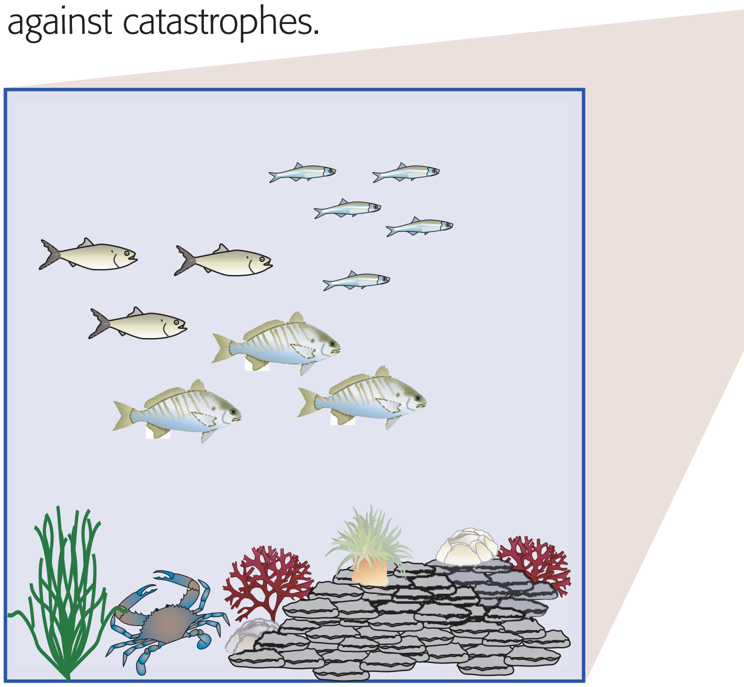
Fish and invertebrates in marine reserves grow older and bigger, allowing them to produce many more offspring.



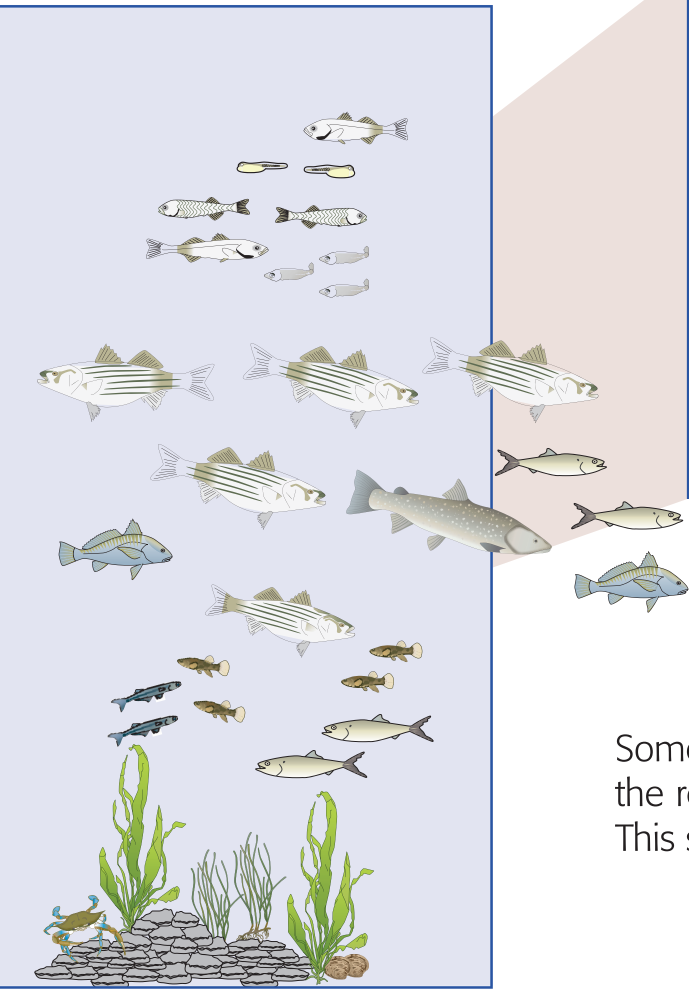
A network can function to protect multiple habitats and species and to provide insurance against catastrophes.

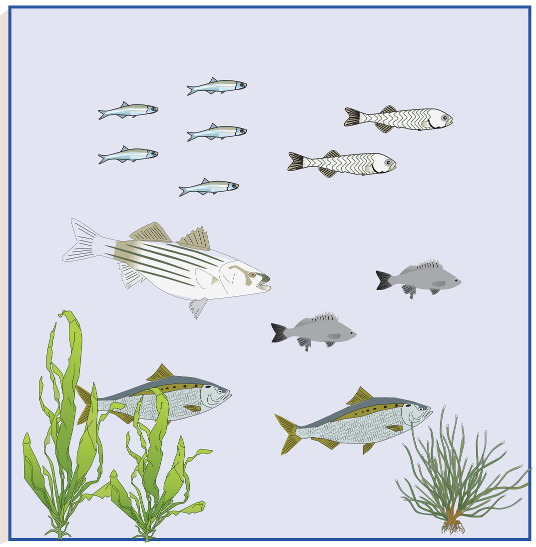
Because disturbance to the bottom is not allowed, bottom habitats can support healthy ecosystems.





Because fishing and other extractive activities are not allowed, marine reserves typically have more biomass (abundance of plants and animals), density (number of plants or animals in a given area), and species diversity (number of species) than areas outside.





Networks of marine reserves that protect different habitats can also protect species at different stages in their life cycles.

Some adults, juveniles, and larvae move out of the reserve to grow and reproduce elsewhere. This spillover helps outside fisheries to thrive.

Marine reserves with straight line boundaries are easier to enforce because the boundaries are easier for users to recognize.

Source: Partnership for Interdisciplinary Studies of Coastal Oceans. 2007. Science of Marine Reserves. www.piscoweb.org. 22 pages.
Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols/), University of Maryland Center for Environmental Science.

Activity: Biodiversity

OVERVIEW

In this lesson, students will explore the biodiversity of two National Oceanic and Atmospheric Administration (NOAA) National Marine Sanctuaries. Following a discussion of the term "biodiversity" and why biodiversity is important, students will take virtual trips (via video footage) to Cordell Bank National Marine Sanctuary, located off the California coast and the Hawaiian Islands Humpback Whale National Marine Sanctuary. They will then work in groups to further explore one of the two ocean treasures, noting the types of wildlife the sanctuary supports, the importance of the ecosystem, and the threats it faces. Groups will also consider how each sanctuary's location might affect its health and long-term outlook. To conclude, the class will come back together to share their findings, and compare and contrast the two national marine sanctuaries.

This lesson is one in a series exploring the history, biology, and ecology of the national marine sanctuaries. It was developed for *National Geographic's* Oceans for Life program, in collaboration with and with support from NOAA.

FOCUS

Biodiversity

GRADE LEVEL

6 - 8

FOCUS QUESTIONS

- What is biodiversity, and why is it important?
- How does the location of a sanctuary affect its long-term outlook?

LEARNING OBJECTIVES

Students will:

- define biodiversity and ecosystem;
- understand the importance of biodiversity to an ecosystem;
- explore the threats to Cordell Bank and the Hawaiian Islands Humpback Whale National Marine Sanctuaries; and
- consider the relationship between the location of each sanctuary and the long-term outlook for its health.

MATERIALS

- Computer with internet access (Note: all information can be pre-downloaded and printed)
- Blank index cards
- Small magnets or tape for attaching cards to the blackboard
- *Xpeditions* atlas maps of California (available at http://www.nationalgeographic.com/xpeditions/atlas/index.html?Parent=usofam&Rootmap=usca&Mode=d&SubMode=w) and Hawaii (available at http://www.nationalgeographic.com/xpeditions/atlas/index.html?Parent=usofam&Rootmap=usha&Mode=d&SubMode=w)

AUDIO VISUAL MATERIALS

- Biodiversity Video (http://mm.coexploration.org/video/tcoe/vtw06/bbflv/index.html)

TEACHING TIME

- 3-4 hours

SEATING ARRANGEMENT

- Whole-class instruction and small group activities

KEY WORDS

- Biodiversity, Cordell Bank National Marine Sanctuary, Hawaiian Islands Humpback Whale National Marine Sanctuary, marine conservation, ecosystem, populations

PREPARATION

- Download and prepare video clips
- Print *Xpeditions* maps

LEARNING PROCEDURE

Explain to students that in this lesson, they will be answering the following questions:

- What is biodiversity?
- Why is biodiversity important?
- How does the location of a sanctuary affect its long-term outlook?

As a class, create working definitions for the words *ecosystem* and *biodiversity.* Brainstorm a list of the organisms found in your local ecosystem and write the list on the board. Discuss with the class the importance of biodiversity. Elicit their opinions on why biodiversity is important and in what ways preserving biodiversity enhances the life of local people. Ask students to think of ways in which preserving biodiversity locally might have a national or global effect. Encourage them to think about the far-reaching effects of habitat destruction and species loss. Some resources to help with this discussion include:

- Loss of Diversity and Extinctions: http://www.globalissues.org/article/171/loss-of-biodiversity-and-extinctions
- New Medicines at Risk from Biodiversity Loss: http://www.sciencedaily.com/releases/2003/10/031017073822.htm

Development: As a class, locate Cordell Bank and Hawaiian Islands Humpback Whale National Marine Sanctuaries on the maps. Explain that both sanctuaries were established to protect and support marine ecosystems. Have pairs of students brainstorm a list of characteristics of marine ecosystems. After five minutes, have student pairs share their answers with the class and record the list on the board or on chart paper. Show students the introductory video clip (http://www.ngsednet.org/community/resources_view.cfm?community_id=128&resource_id=5659).

Divide the class into research teams of four or five. Assign half of the teams to research Cordell Bank National Marine Sanctuary (http://cordellbank.noaa.gov/) and the other half to research Hawaiian Islands Humpback Whale National Marine Sanctuary (http://hawaiihumpbackwhale.noaa.gov/). Teams may also use the Encyclopedia of the Sanctuary (http://www8.nos.noaa.gov/onms/park/) for their research. Tell students to focus on the following:

- Location of the sanctuary (have them mark it on the map)
- Characteristics of the ecosystem that the sanctuary supports (water temperature, physical geography, etc.)
- Wildlife present in the sanctuary
- Importance of the ecosystem in general or any particular species found in the sanctuary
- Proximity and culture of human settlements near the sanctuary
- Challenges facing the sanctuary and whether or not they are human-induced

Give each team about 20 index cards. As they research the above points, teams should use index cards to describe the oceanographic, meteorological, and physical features of the sanctuary. They should also create a card for each species found in the sanctuary, writing its name on the front and any other pertinent information about it (is it endangered? what threats does it face? is it unique to this area? what is its food source?) on the back. (These cards will be used later in a whole class activity.) Give groups about 45 minutes to an hour to complete their research. When teams have completed their research, bring the class back together and invite teams to share their information. Have teams present their findings first for one sanctuary then the other. Instruct the students to take notes on the findings of each team.

After each team has presented their findings, draw a large Venn diagram on the board. Using one circle to represent Cordell Bank National Marine Sanctuary and one to represent the Hawaiian Islands Humpback Whale National Marine Sanctuary, have the students place their cards on the diagram using magnets or tape. When all the cards have been placed, lead a class discussion about the results. Ask students:

- Which aspects of the physical environment are the same in both sanctuaries? Which are different?
- How many species are found in both sanctuaries?
- Are there more species that are unique to one or the other sanctuary, or can many be found in both? Why do you think this is?
- Which species can be found in both sanctuaries? Do they use the sanctuaries for different purposes (breeding, feeding, etc.)? What does this imply about the importance of the sanctuaries?

Direct the students to go back to their teams and return the students' species cards to them. Tell them they will now be investigating food webs. (A review of food webs can be found at http://www.vtaide.com/png/foodchains.htm.) Using their species cards, each team should create a basic food web for their sanctuary. Have each team use half of the board to arrange their cards and use arrows to show which animals eat and are eaten by others. When the food webs are complete, have students return to their seats. Ask students to consider the effects of changes to the environment or one or more species in each food web. For example, ask "What would happen if there were a sudden dying of phytoplankton in the Cordell Bank sanctuary?" Students should note that as primary producers, phytoplankton support the entire food web and the effects would be felt throughout. Help guide students in reflecting on the effects different changes have on the various levels of the food web.

CLOSING

Explain that Hawai`i is the most important breeding ground for North Pacific humpbacks, and people and humpbacks are increasing their shared use of the same marine habitats. Ask students how this shared use might pose a threat to the Hawaiian Islands Humpback Whale National Marine Sanctuary's ecosystem. Another population of humpback whales, along with blue whales, visits Cordell Bank in the summer to feed on krill. How might changes in the ecosystem at Cordell Bank affect the whale population? Have groups of students explore some of the threats to these ecosystems (tourism, overfishing, destruction of habitat) and report back to the class.

SUGGESTED STUDENT ASSESSMENT

Have students write essays that provide information about one of the two sanctuaries, focusing specifically on the challenges faced by the sanctuary and the outlook for the future health of the ecosystem. Teachers or students may use this rubric (http://interactives.mped.org/view_interactive.aspx?id=726&title=) for evaluation purposes.

EXTENDING THE LESSON

- Have students research a local conservation area and prepare posters detailing the area's biodiversity, threats to its health, and importance of preservation.
- Have students use the Hotspots Explorer (http://www.biodiversityhotspots.org/xp/Hotspots/Pages/default.aspx) from Conservation International to explore biodiversity hotspots around the globe. Ask students to select three hotspots that they think are most worthy of preservation. Students should be prepared to provide convincing arguments for their choices.
- Research other national marine sanctuaries to compare and contrast their physical environments and the variety of species found in each underwater treasure.

CONNECTIONS TO OTHER SUBJECTS

Geography, ecology, biology, social studies

NATIONAL SCIENCE EDUCATION STANDARDS

C: Populations and Ecosystems: "A population consists of all individuals of a species that occur together at a given place and time. All populations living together and the physical factors with which they interact compose an ecosystem."

C: Populations and Ecosystems: "The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem."

NATIONAL GEOGRAPHY STANDARDS

Standard 8: "The characteristics and spatial distribution of ecosystems on earth's surface"

Standard 6: "How culture and experience influence people's perceptions of places and regions"

Standard 14: "How human actions modify the physical environment"

OCEAN LITERACY: ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

Principle 5: The ocean supports a great diversity of life and ecosystems

Principle 6: The ocean and humans are inextricably linked

FOR MORE INFORMATION

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Correction Notice

In the special issue featuring NOAA Fisheries Service (Volume 26, Number 1, 2010), in the article featuring NOAA's Teacher at Sea Program on pages 24-26, we'd like to correct the statement that no teachers have come from South Dakota, when in fact it should read North Dakota. The Teacher at Sea Program will, however, have a teacher participating in the program from North Dakota this 2010 season.

Call for Papers

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The editors of *Current: The Journal of Marine Education* are seeking articles for upcoming general issues. We hope to review and publish articles on topics related to marine education. We seek original manuscripts that describe research, lessons, resources, or strategies for teaching marine and aquatic lessons to a variety of audiences. Please submit articles and/or activities by September 13, 2010 to Lisa Tooker at ltooker@sbcglobal.net for consideration.

Pelagic Reserves for Marine Top Predators: How Big and How Many?

By David Hyrenbach

While the concept of pelagic reserves may seem unreasonable due *to the vast movements of many whales, seabirds, and large predatory fishes (e.g., marlins, sharks, tunas), recent conceptual and technological advances have provided managers with the necessary tools to design and manage MPAs in oceanic systems and the open ocean beyond national territorial waters. In particular, advances in satellite-derived information, such as animal tracking and remote sensing imagery, are allowing scientists to define the habitats of protected species and to monitor oceanographic features and predator movements. Thus, it is becoming increasingly evident that pelagic reserves are not only feasible, but necessary to facilitate the long-term conservation of oceanic species and pelagic ecosystems.*

Marine protected areas are increasingly being used as tools for protecting valuable and sensitive ecological, cultural, and fishery resources throughout the world. Within this context, MPAs designed to conserve biodiversity can provide a wide range of protections for species, habitats, and ecosystems. For instance, no-take marine reserves, a type of highly protected MPA, often prohibit direct harvesting and indirect impacts on protected species and their habitats, while sanctuaries provide broader protections against more diffuse ecosystem-level impacts such as those involved in oil and gas extraction. In recent years, there has been mounting interest in the development of pelagic reserves—large MPAs designed to protect oceanic species and their habitats. In particular, marine ecologists have advocated the use of reserves to protect highly mobile marine mammals, birds, turtles, and sharks from incidental fisheries mortality and other impacts to their habitats. Because evidence suggests that top marine predators control populations of mid-level predators and hence help to structure marine food webs, the need to maintain their roles in marine ecosystems is critical.

LIFE HISTORY CONSIDERATIONS

Because MPAs have many different goals, their designs and management plans vary widely. Reserves designed to protect pelagic species and their oceanic habitats are based on design concepts driven by their biology and the associated oceanographic characteristics of their habitats. For example, managers need to understand critical life history aspects of the focal species: where and when they reproduce and feed; whether different life stages and sexes use distinct habitats; if they migrate seasonally between breeding and foraging grounds; and if they repeatedly use specific migratory pathways. Equipped with this information, managers can determine whether important life history processes are associated with habitats that can be mapped in time and space. Even though a given species may rely on specific features during certain seasons or ages, they may use widely distributed resources at other times. Thus, reserves may not be practical or effective throughout the entire life cycle of the species, but will only represent a feasible conservation option at those times and locations where the species concentrates in predictable features to breed or forage. These predictable aggregations provide excellent opportunities for the creation of reserves to protect these critical life history stages.

Sea turtles migrate long distances between their feeding grounds and places where they nest.

While reserves have long been used in coastal waters to protect benthic species and habitats, like coral reefs and mangroves, they are increasingly being considered to protect highly mobile species and oceanic habitats spurred by increasing evidence that these far-ranging species concentrate in predictable habitat features. Depending on the life history and habitats of the protected species, pelagic reserves can adopt four basic designs: hotspot reserves, reserve networks, basin-wide reserves, and ecosystem reserves.

HOTSPOT RESERVES

Wildlife reserves have long been used on land and at sea to protect relatively small areas of high biological value, because they harbor dense aggregations of protected species, sensitive or critical habitats, or areas of high biological diversity. For example, the eastern Pacific gray whale (*Eschrichtius robustus*) breeds off Baja California (Mexico) during the winter, spends the summer foraging in the Bering and Chukchi Seas, and migrates along coastal waters from Baja California to Alaska every fall and spring. A small (approximately 3,700 km^2) whale sanctuary encompassing two lagoons (Laguna Ojo de Liebre and Laguna San Ignacio) and the surrounding land was designated by the Mexican federal government in 1971 as a whale sanctuary to protect the gray whale calving grounds from development and associated threats, such as oil spills and coastal development. Research, recreation, tourism, and environmental education are the only permitted activities in the sanctuary, and whale watching is controlled.

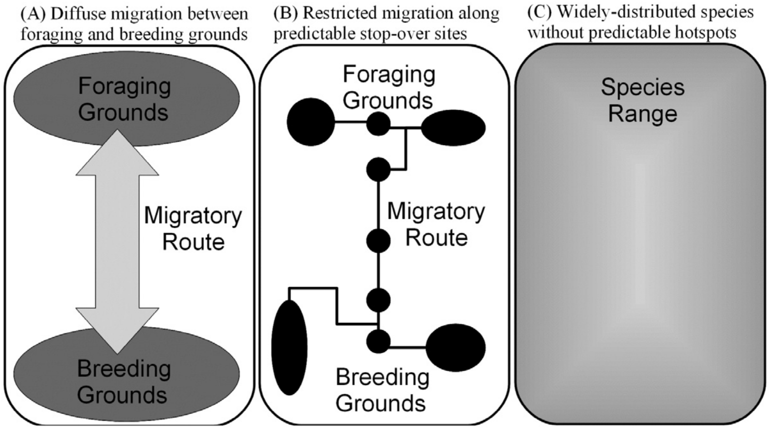

Figure 1. Diagram illustrating three different MPA scenarios: (A) two hotspot reserves protect key foraging and breeding grounds, connected by a diffuse migratory pathway; (B) a network of reserves protects stop-over sites along a fairly restricted migratory pathway, connecting predictable foraging and breeding grounds; and (C) a large seascape reserve encompasses the entire range of a widely distributed protected species. The shading indicates the abundance of the species, ranging from white (absence) to black (high density).

Species like the Pacific gray whale (*Eschrichtius Robustus*) have predictable migration patterns and could benefit from hotspot reserves.

Because gray whales have a fairly predictable oceanic migration, other sanctuaries could be created to protect this species during other parts of its life cycle. In particular, whale concentrations in their Alaskan summer-time foraging grounds could be mapped and protected. Potentially, other protective measures could also be used to mitigate human impacts along their migratory route between the breeding and foraging grounds [Figure 1(A)]. Due to the shared responsibility for the conservation of this species between Canada, Mexico, and the U.S., the Commission for Environmental Cooperation (CEC) selected the gray whale as a species of common conservation concern, a designation which involves identifying ecologically important areas for consideration as protected areas within the framework of the Bering to Baja Conservation initiative.

Even though MPAs are more difficult to design and to implement in the open ocean than in coastal areas, they could help to protect oceanic, highly mobile species like the fin whale (*Balaenoptera physalus*). Fin whales are found in all the world's oceans, but occasionally concentrate in dense aggregations susceptible to human impacts. The Pelagos Sanctuary for Mediterranean Marine Mammals was established in the Ligurian Sea (Western Mediterranean) in 1999 to protect a large local population of fin whales from accidental entanglement in drift nets, ship strikes, and pollution. This sanctuary covers an area of 87,492 km^2, and comprises the waters of three nations (France, Italy, Monaco) and 46,371 km^2 of high seas waters beyond areas under national jurisdiction. This MPA encompasses a persistent oceanographic front overlaying the continental shelf-break and upper slope (200-2000 m depth). These productive waters are believed to be the main feeding ground for fin whales in the Mediterranean basin, with an estimated 3,500 individuals using the area in summer. The sanctuary provides for enforcement of existing legislation by the three range nations to reduce a variety of impacts. Discharge from dredges and power boat racing are both prohibited, and whale watching is regulated.

RESERVE NETWORKS

Because many cetaceans (whales, dolphins, and porpoises) engage in large seasonal migrations (over 1,000s of km), MPAs capable of encompassing their entire range would have to be very large, in some cases spanning entire ocean basins. Alternatively, multiple linked MPAs may be required to afford protection to these migratory species throughout their year-long cycle, by protecting their calving areas (winter), their foraging grounds (summer), and their seasonal migratory routes [Figure 1(B)], especially where they intersect with intense human activities such as shipping. Such a system of MPAs would require an integrated management plan involving multiple countries and protective measures in the high seas, beyond national jurisdiction, likely under the UN Convention on the Law of the Sea.

The International Union for the Conservation of Nature (IUCN) has defined MPA networks as "a collection of individual marine protected areas operating cooperatively and synergistically, at various spatial scales, and with a range of protection levels, in order to fulfill ecological aims more effectively and comprehensively than individual sites could alone. The network will also display social and economic benefits, though the latter may only become fully developed over long time frames as ecosystems recover" (WCPA/IUCN 2007). While reserve networks could be used to protect cetaceans throughout their migratory routes, network feasibility and design will ultimately depend on the predictability of species' foraging and breeding grounds, and the migratory routes connecting them. Thorough assessments will be required to guide these networks, because different threats have characteristic footprints that influence the ability of specific management actions to mitigate their impacts. In particular, the inability of reserves to mitigate large-scale human impacts with basin-wide footprints, such as climate change, noise pollution, and marine debris, emphasizes the need for a comprehensive approach to oceanic conservation, including the judicious use of MPAs with diverse objectives, designs, and management plans.

LARGE-SCALE RESERVES

In addition to reserves designed to protect cetacean hotspots from focused impacts, large seascape reserves may be required to protect widely distributed species from far-reaching threats over their entire ranges [Figure 1(C)]. For instance, vast expanses of the ocean beyond national jurisdiction have been set aside as international cetacean sanctuaries under the auspices of the International Whaling Commission (IWC), exclusively to protect large whale populations from commercial whaling. Currently, two such IWC sanctuaries exist: the 1979 Indian Ocean Sanctuary and the 1994 Southern Ocean Sanctuary. Together, these two sanctuaries cover the entire ranges of several Indian Ocean cetaceans that migrate seasonally from tropical breeding grounds to the Antarctic. The Indian Ocean and Southern Ocean Sanctuaries have been continued after scientific evaluations conducted every 10 years and are still in existence. While these sanctuaries do provide research and management benefits to large whale populations, their major limitation is the continued hunting of whales (largely Antarctic minke whales, *Balaenoptera bonaerensis*) by Japanese scientific permit whaling. This harvesting remains a major unresolved issue in the management of large whale populations and the monitoring of the Antarctic marine ecosystem.

Moreover, two proposals for the establishment of additional IWC sanctuaries in the South Pacific Ocean and the South Atlantic Ocean have so far failed to gain the required three-quarters majority at annual IWC meetings. Thus, large whale stocks in these two oceans are not currently protected from commercial whaling throughout their life cycle, since these populations exit the protected waters of the Southern Ocean Sanctuary (SOS) to breed in the tropics, or from scientific permit whaling. Despite the failure to agree to the establishment of new IWC sanctuaries, recent assessments of the two existing sanctuaries have stressed the need for broader management goals aimed at establishing a comprehensive ecosystem-based management of cetaceans within sanctuary waters.

ECOSYSTEM RESERVES

Even though reserve networks may be critical for protecting migrating species throughout their life cycle, they may not suffice to preserve the key ecological interactions and ecosystem processes supporting them. In recent years, scientists have called for the establishment of large ecosystem-level reserves to protect some of the last remaining stretches of ocean that have not been harmed by human activities such as overfishing and pollution. While most existing marine reserves have been created to protect endangered species and their habitats, these novel large scale, no-take reserves would be created preemptively to ensure that marine regions with high biodiversity or ecological value remain undisturbed. Basically, these ecosystem reserves would act as an insurance policy against future ecological degradation. Furthermore, these sites would facilitate long-term research opportunities as reference sites, critical for monitoring changes in marine ecosystems. The *Last Ocean* initiative, which advocates for the establishment of a basin-wide, no-take reserve to protect the diverse and productive Ross Sea near Antarctica, illustrates the concept of ecosystem-level MPAs in the open ocean.

CONCLUSIONS

MPAs are increasingly being used to protect cetaceans throughout the world, including pelagic species in oceanic habitats. As more pelagic reserves are established for biodiversity conservation, a more comprehensive approach for their design and management is emerging, built upon four principles: (i) all MPA designs must include clear goals and management plans that are periodically evaluated and revised, supported with adequate surveillance and enforcement; (ii) small hotspot reserves can

Pelagic MPAs can help conserve endangered species like the northern right whale *(Eubalaena glacialis)*.

be used to protect predictable breeding and foraging sites; (iii) reserve networks are needed to protect the entire life cycle of migratory species; and (iv) large seascape reserves are required to address broader ecosystem-level management considerations, including the long-term conservation and monitoring of ocean ecosystems.

Ultimately, marine reserve designs are driven by the natural history of the species to be protected and by the threats affecting them. For instance, while hotspot reserves can protect species with small ranges at a given life history stage from focused threats (e.g., incidental mortality from fisheries and ship strikes), large seascape reserves (often basin-wide) are needed to protect far-ranging species with seasonal migrations from widely distributed threats (e.g., commercial whaling). Nevertheless, reserves need not completely remove human impacts from the entire range of a species to be effective conservation tools; small decreases in mortality rates from entanglement and ship strikes can help reverse the population declines of protected whale species. Thus, fine-scale protective measures targeted at critical foraging and breeding sites can yield large conservation pay-offs, especially for species with small populations under pressure (e.g., the Pacific and Atlantic northern right whale, *Eubalaena glacialis*).

In those instances when cetaceans concentrate in predictable areas to breed (e.g., gray whales in Baja California) or to forage (e.g., fin whales in the Ligurian Sea), small reserves can protect these important habitats. These hotspot reserves can target productive habitat features associated with the sea floor (e.g., banks, seamounts, canyons, shelf-breaks) and with predictable locations where water flow causes high-localized productivity (e.g., upwelling plumes) or the concentration of weakly swimming zooplankton prey (e.g., convergence zones). Because these bathymetric (sea floor) and hydrographic (water movement) features vary in size and predictability, different reserve designs will be required to encompass top predator distributions in these habitats.

Existing cetacean MPAs (e.g., Pelagos and IWC Sanctuaries), ongoing initiatives for MPA networks spanning entire large marine ecosystems (e.g., Bering to Baja), and recent closures of high seas pockets in the Pacific Ocean to tuna fishing (Currie and Wowk 2009), underscore the potential use of international reserves in the conservation of pelagic species, including marine mammals, birds, turtles, and predatory fishes.

The *Last Ocean* initiative to establish a basin-wide, no-take reserve in the Ross Sea illustrates the advent of ecosystem-level MPAs on the international agenda. This reserve would protect marine top predators and the ecosystem processes they depend upon in perpetuity, by stopping the harvesting of marine resources—including scientific permit whaling—in this vast region of Antarctica. Already in October 2009, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) designated a similar ecosystem-level, high seas reserve south of the South Orkney Islands (South Atlantic Ocean). This reserve is intended to provide a scientific baseline for research, to increase resilience to climate change, and to conserve important predator foraging areas and representative examples of pelagic and benthic bioregions. Thus, a wide array of human activities, including fishing, ship discharges, dumping, and shipping, will be prohibited.

The future of pelagic conservation will involve the implementation and evaluation of fine-scale and basin-wide protections, including marine reserves designed to protect biological hotspots, bottlenecks in the migratory pathways of highly mobile species, vast seascapes encompassing the entire life cycle of protected species, and entire marine ecosystems. A diverse array of MPAs, both multiple-use and no-take, will be required, alongside other fisheries and conservation actions, to help protect and monitor far-ranging species and their oceanic habitats.

WEB LINKS

- Case Study 1- the Pelagos Sanctuary: **http://www.cetaceanhabitat.org/pelagos.php**
- Case Study 2- International Whaling Commission Sanctuaries: **http://www.iwcoffice.org/conservation/sanctuaries.htm**
- Case Study 3- The Bering to Baja Initiative: **http://www.cec.org/files/PDF/BIODIVERSITY/IMpaper_en.pdf**
- Case study 4- Ecosystem-level MPAs: **http://lastocean.com/story/overview/read/**

FOOD FOR THOUGHT

Visit the American Cetacean Society website (http://www.acsonline.org/factpack/) and compare the cetacean distribution maps. Read the species profiles and discuss possible marine reserve designs for the different species. Consider the following:

- Do the species have large or small ranges?
- Are their breeding and foraging grounds together or separated?
- Do the species go on vast seasonal migrations? Hint: you may want to consider the following three species:
    - Gray whale: http://www.acsonline.org/factpack/graywhl.htm
    - Fin whale: http://www.acsonline.org/factpack/finwhl.htm
    - Franciscana dolphin: http://www.acsonline.org/factpack/Franciscana.htm

The number and size of MPAs varies throughout the world. Look for existing MPAs in your region on the interactive map and the regional lists. What parts of the world have the highest/lowest concentrations of MPAs? Where are the world's largest MPAs?

- Interactive map: http://www.mpaglobal.org/index.php?action=aboutus
- Regional lists: http://www.mpaglobal.org/index.php?action=summary_by_country

Effective MPAs need management plans devised by scientists together with local stakeholders. Management plans describe the specific conservation goals for the individual species and the entire ecosystem to be protected, the research and educational needs, the types of allowed and restricted uses, the management and enforcement regimes required, and the schedule for periodic monitoring and review of the MPA goals and performance. To learn more about the threats faced by cetaceans and the potential management actions to mitigate these threats, consult these MPA management plans at http://www.cetaceanhabitat.org/management_plans1.php.

Northeastern offshore spotted dolphins are believed to migrate inshore in the fall and winter months and offshore in the spring.

Read about the scientific rationale for creating ecosystem-level MPAs, and their importance for long-term conservation, resource management, and research at http://lastocean.com/.

FOR MORE RESOURCES

- Baja California to Bering Sea Ecosystem: **http://www.mcbi.org/what/b2bcd.htm**
- International Whaling Commission, Scientific Permit Whaling: **http://www.iwcoffice.org/conservation/permits.htm**

For more information on the design and implementation of the Pelagos Sanctuary, refer to NCEP module 498 ("The Pelagos Sanctuary for Mediterranean Marine Mammals"), available at http://ncep.amnh.org.

David Hyrenbach, Ph.D., is an assistant professor at Hawai'i Pacific University and an adjunct professor at the Duke University Marine Laboratory. His research focuses on mobile marine predators, and the design and effectiveness of protected areas in pelagic systems. Born in Spain, David completed his Ph.D. at the Scripps Institution of Oceanography. In 2007, he was awarded a Pew Fellowship in Marine Conservation to work on the distributions of marine birds, turtles, and mammals in the Alborán Sea, Western Mediterranean. His current research focuses on two main areas: how does oceanographic variability in time and space shape the distribution and community structure of pelagic vertebrates, and how do these habitat associations influence the efficacy of spatially explicit management strategies for their conservation.

REFERENCES

Currie, D., and K. Wowk. (2009). *Climate Change and Co_2 in the Oceans and Global Oceans Governance*, CCLR 4:387-399.

WCPA/IUCN. (2007). *Establishing Marine Protected Area Networks: A Guide for Developing National and Regional Capacity for Building MPA Networks*. Available at: http://www.medpan.org/_upload/893.pdf

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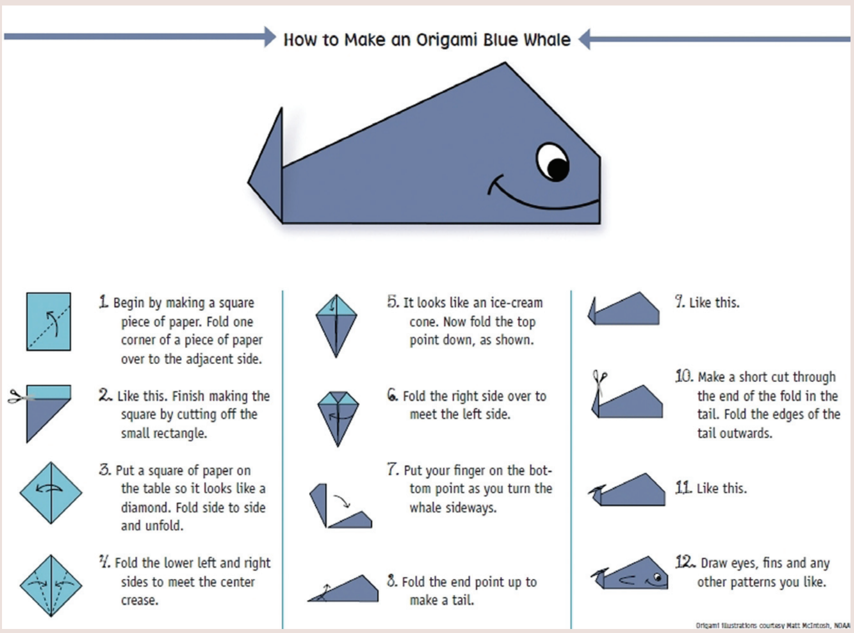
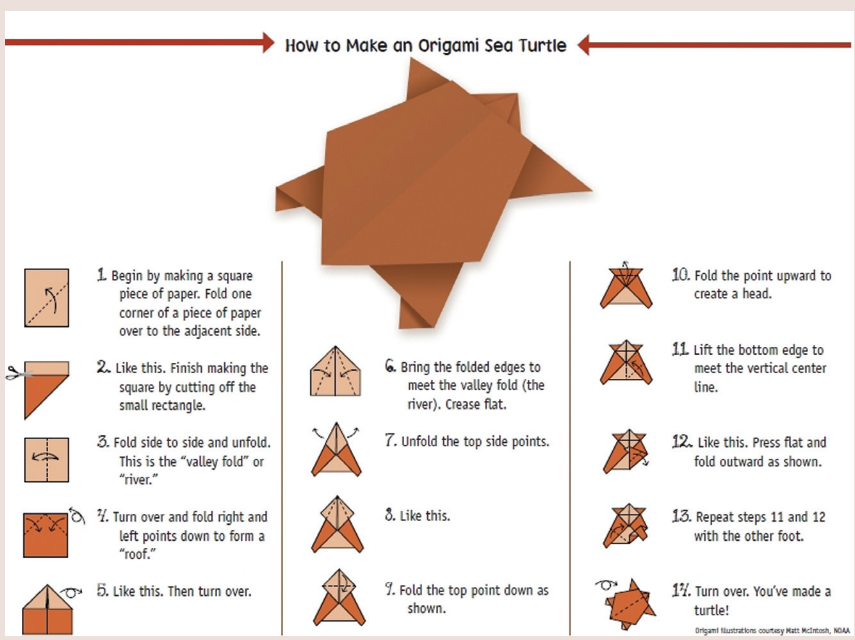
Pages 32-33: Courtesy of NOAA

Activity: Origami Whale and Turtle

Want to learn how to make endangered species origami? Check NOAA's National Ocean Service Education website at http://oceanservice.noaa.gov/education/games.html and teach your class about these important endangered animals!





New Stresses, New Strategies: Managing Marine Protected Areas in an Age of Global Environmental Change

By Daniel Gleason

With the increasing threat and ongoing impacts of global change, *the concepts behind design and management of MPAs continue to evolve. No longer can MPAs be viewed and managed solely within the framework of local stressors. Rather, MPA managers must consider how global change phenomena may alter the ability of organisms to respond to local stressors and whether new management actions should be attempted.*

Federal marine protected areas (MPAs) in the United States are under the jurisdiction of several government agencies and are governed by no less than eight separate acts (Table 1). These MPAs are the best-known form of site-based management for conserving marine life and critical habitats. While used in the past primarily to safeguard marine biodiversity, the goals and expectations of MPA implementation have seen steady expansion. Depending on the MPA, these goals may include not only conservation of biodiversity and preservation of habitat, but fisheries management to improve or restore local fisheries stocks, and societal benefits such as economic vitality, environmental stewardship, and education (Hatziolos et al. 2006).

IMPACTS OF GLOBAL CHANGE ON MARINE ORGANISMS

While numerous stressors can affect marine ecosystems (e.g., Keller et al. 2009; McLeod et al. 2009), these generally fall into four broad groups: overfishing, land-based pollution, habitat destruction and degradation, and global change (Knowlton and Jackson 2008). The first three categories of stressors represent more traditional motives for implementing MPAs. These stressors often can be managed effectively on a local scale, even though their scope of impact may range well beyond MPA boundaries. The addition of global change stressors has complicated MPA management because of their widespread impact and the fact that the response of organisms to global change may affect their ability to respond to stressors that act on more local scales (Knowlton and Jackson 2008). This article uses the more general term, "global change," rather than "global climate change" or "climate change," because anthropogenic impacts from increased levels of carbon dioxide (CO_2) emissions in the atmosphere have far greater effects than solely increasing temperatures.

Two consequences of increased CO_2 emissions that are of immediate relevance to marine ecosystems worldwide are temperature increases and ocean acidification. Atmospheric temperatures have risen significantly over the last 50 years, with the oceans absorbing more than 80% of the excess heat added to the climate system. As a result, studies show that the 0 to 700 m depth layer of the ocean warmed by an average

Type of MPA/MMA	Number of Sites	Administration	Mandate
National Marine Sanctuary	13	NOAA/National Marine Sanctuary Program	National Marine Sanctuaries Act
Fishery Management Area	216	NOAA/National Marine Fisheries Service	Magnuson-Stevens Act, Endangered Species Act, Marine Mammal Protection Act
National Estuarine Research Reserve	27	NOAA/Office of Coastal and Resource Management	Coastal Zone Management Act
National Park	42	National Park Service	NPS Organic Act
National Monument	7	National Park Fish Wildlife Service	NPS Organic Act, Antiquities Act
National Wildlife Refuge	109	U.S. Fish and Wildlife Service	National Wildlife Refuge System Administration Act

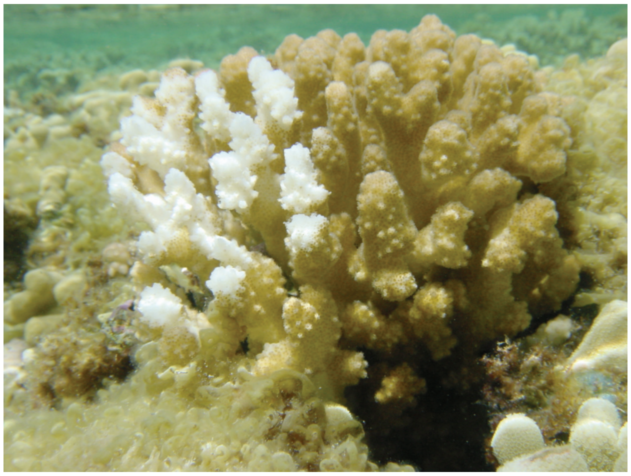
Table 1. Types of marine protected areas, administration, and legislative mandates.

of 0.1°C worldwide between 1961 and 2003 (Bindoff et al. 2007). These increasing sea temperatures influence organismal processes such as foraging for food, growth, reproductive timing, and larval duration and dispersal, with ultimate impacts on the geographic ranges of species.

While a 0.1°C increase in ocean temperatures may not seem like much, shifts pole-ward in some zooplankton, intertidal invertebrate, and fish communities have already been observed (reviewed in Walther et al. 2002). For example, an analysis of the distributions of North Sea fish species between 1977 and 2001 found northward shifts of 48 to 403 km in 15 of 36 species (Perry et al. 2005). Shifts in distributions of this magnitude complicate efforts to manage commercially exploited fish stocks because species-specific differences in abilities to adjust ranges may alter historical overlaps between competing species, as well as between predators and prey. At the other end of the spectrum, species unable to expand their geographic ranges may be required to adapt to new temperature regimes, or compete with influxes of new residents that may be driven to extinction. As an example, many species of reef-building corals are living near the upper limit of their thermal tolerance (see discussion under "Ecosystem Resilience") and may possess no or limited ability to tolerate higher temperatures. A whole host of other environmental challenges are associated with temperature increases and may impact marine organisms. These include: melting polar ice, rising sea levels, increasing storm frequencies and intensities, unknown effects on surface currents, alterations in ocean circulation and stratification patterns, the spread and emergence of diseases, and increasing or decreasing freshwater input at the local scale.

Elevated CO_2 concentrations in the atmosphere also lower oceanic pH, making waters more acidic. This process occurs as CO_2 is absorbed by surface waters of the oceans and reacts with seawater to form carbonic acid (H_2CO_3). The acid then releases hydrogen ions that reduce the water's pH. The pH scale ranges from 0 (acidic) to 14 (basic) and is logarithmic, so a change of one pH unit is equal to a ten-fold difference in hydrogen ion concentration. The total inorganic carbon content of the world's oceans increased by 1.2×10^{11} tons from 1750 to 1994; and continues to rise because oceanic waters absorb about one-third of the excess CO_2 released into the atmosphere each year (Bindoff et al. 2007). Current estimates are that the pH of ocean surface waters has decreased by about 0.1 units (from 8.2 to 8.1 pH units) since the beginning of the industrial revolution (Feely et al. 2004). Furthermore, time series data for the last 20 years show a trend for decreasing pH of 0.02 pH units per decade (Bindoff et al. 2007).

By far the greatest threat of reducing pH is to organisms, including reef-building corals that build skeletal material from calcium carbonate ($CaCO_3$). Hydrogen ions (H^+) that are released from carbonic acid (H_2CO_3) combine with carbonate (CO_3^{2-}) to produce bicarbonate (HCO_3^-). The sum of these reactions is reduced availability of the carbonate needed for producing skeletal material and shells. Interestingly, because CO_2 has greater solubility in cooler waters, calcifying organisms (such as sea urchins, cold-water corals, coralline algae, and phyto-, zoo- and ichthyo-plankton) residing in temperate and Polar Regions appear to be the most threatened by ocean acidification (Feely et al. 2004). Appropriately, ocean acidification is a rapidly expanding area of study as scientists strive to identify the exact reductions in pH levels that will impact the broad array of organisms that can potentially be affected.



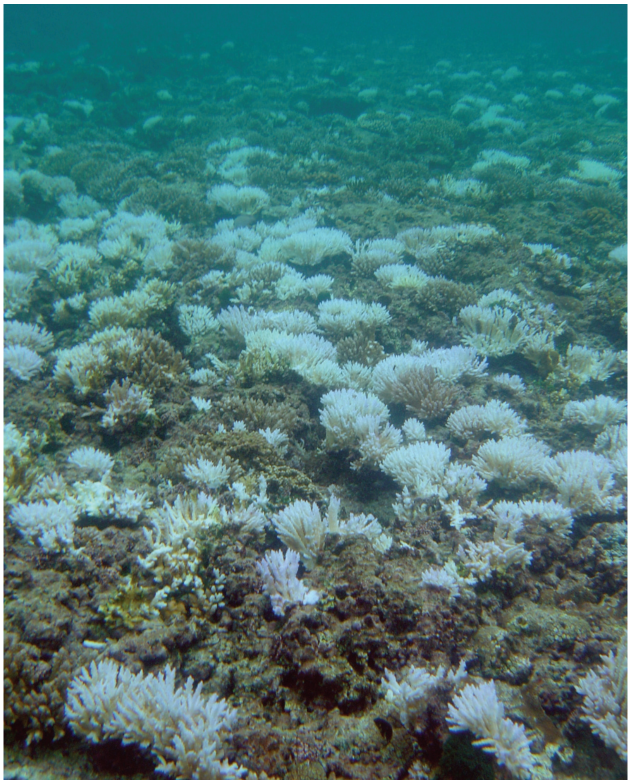


Figure 1. The white branches in the top photograph represent regions of the coral colony where symbiotic algae (known as zooxanthellae) have been lost. The bottom photograph shows a coral reef in Guam with fairly extensive coral bleaching.

ECOSYSTEM RESILIENCE

One of the key goals of MPAs is to maintain the integrity of ecosystems by fostering ecosystem resilience. According to McLeod et al. (2009), resilience refers to the ability of an ecosystem to maintain key functions and processes in the face of stresses or pressures, either by resisting or adapting to environmental change. Thus, resilience refers to the ability of an ecosystem to maintain a steady state in the face of a disturbance, or return to that same state after a disturbance. For example, in recent years there has been an upsurge in the severity and frequency of coral bleaching events worldwide (Donner et al. 2005). These episodes are most often caused by periods of abnormally high ocean temperatures (≥30 °C). During bleaching events, corals become ghostly white because the single-celled alga that normally resides in their tissues is lost (Figure 1). A reef where the majority of corals show little or no bleaching, or where the corals recover fully and quickly after a bleaching event, would be considered "resilient." Given the goal of maintaining resilient ecosystems, the pressing question for marine managers is: "In the face of local stressors and global change, how can MPAs be managed to maintain ecosystem resilience?" The short answer is to select new areas for protection that are predicted to have high resilience and to manage existing areas to maximize resilience.

Figure 2. Two coral reef sites at Turneffe Atoll, Belize in 2006. If scientific monitoring were initiated today, these two sites would start from radically different baselines. The reef in the top image looks "pristine," but is subject to human impacts such as overfishing and reduced water quality.

Identifying and maintaining ecosystem resilience is challenging. Among other necessary steps, identifying resilient sites for protection requires that ecosystem characteristics indicating resilience are well-defined, identified, and documented. The already onerous task of identifying resilient sites is made even more difficult by the shortage of pristine marine ecosystems to use as a baseline for determining which characteristics should be present (Knowlton and Jackson 2008). Relative to terrestrial systems, extensive exploration of most marine ecosystems began fairly recently and was initiated long after human impacts were already evident. Indeed, recent analyses indicate there is no marine ecosystem in the world that is free of human impacts (Halpern et al. 2008), bringing into question what constitutes a healthy and resilient ecosystem (Figure 2).

Efforts to identify indicators of resilience are not futile, however, and are needed for effective management of marine ecosystems. Traditionally, methods of quantifying ecosystem health involve tracking the abundance of the most conspicuous species over time (Hughes et al. 2005). For example, in coral reef systems the abundance of the major reef-building coral species is often monitored. An ecosystem showing a decline in the diversity and abundance of these corals would be considered to have reduced health and lower resilience. The problem with this approach is that the causes and consequences of changes in abundance of the species being monitored are usually not investigated.

A more recent approach to viewing ecosystem resilience is to focus on suites of species that carry out critical functions within the ecosystem, rather than concentrating on the most conspicuous species. Species groups with equivalent roles in terms of ecosystem function have been dubbed "functional groups" (Steneck 2001). For example, on tropical coral reefs herbivores are vital for allowing more slowly growing, reef-building corals to persist because they graze down rapidly growing algae. Herbivores on reefs are not created equal, however, and can be categorized into three functional groups as follows (Steneck 2001): deep grazing herbivores that remove all algae as well as pieces of the carbonate substrata (e.g., parrotfish, some urchins, Figure 3); denuding herbivores that remove most algae (e.g., surgeonfish, some snails); and non-denuding herbivores that have no or little ability to graze down algae (e.g., damselfish, amphipods). In this system, ecosystem function can be maintained if: 1) high-species diversity and high abundances are maintained for species in all three functional groups; or 2) low-species diversity occurs in one or more functional groups, but abundances for those species that persist are high. Both ecosystem function and resilience are possible in the second scenario because all three herbivore functional groups are present and the high abundance of individuals compensates for the low-species diversity that exists in one or more of the groups.

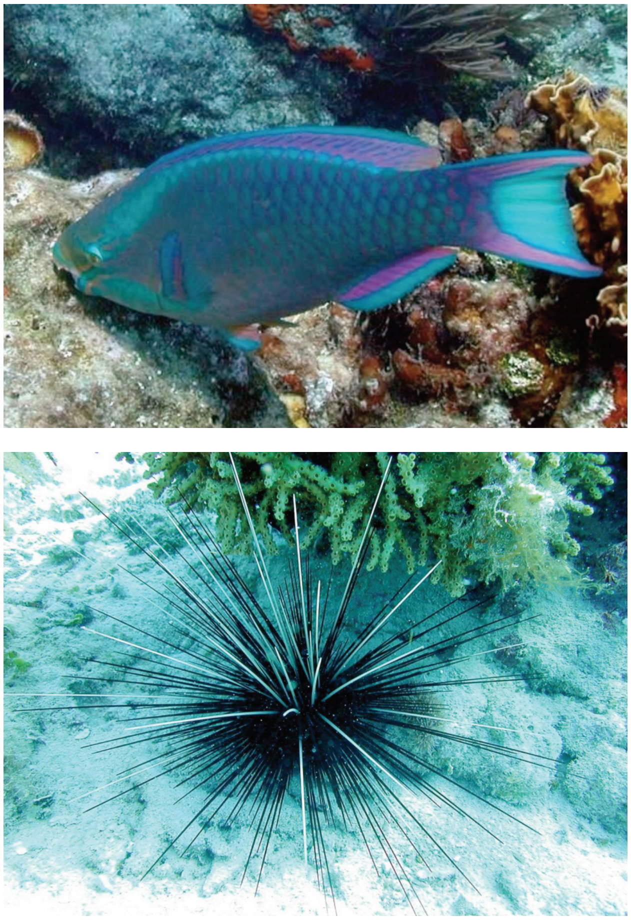


Figure 3. While princess parrotfish (*Scarus taeniopterus*) and long-spined urchins (*Diadema antillarum*) are clearly very different organisms, on coral reefs they belong to the same functional group—deep grazing herbivores that remove all algae as well as pieces of the carbonate substrata.

MANAGING FOR ECOSYSTEM RESILIENCE

The preceding discussion highlights how maintaining species diversity within functional groups incorporates redundancy within ecosystems and safeguards ecosystem function. Thus, managing for diversity is a vital component of sustaining ecosystem resilience, especially in light of the additional stresses imposed by global change. Ultimately, MPA managers can respond to global change challenges that threaten ecosystem resilience by taking actions at individual sites and regionally to ameliorate stressors such as overfishing and excessive input of nutrients; implementing MPA networks that preserve linkages and connectivity among sites; and integrating global change in MPA planning. Incorporating MPA networks and integrating global change in planning represent more recent concepts of management and merit further clarification.

MPA networks maintain ecosystem integrity by preserving the connections that occur naturally among habitat types. These linkages are usually viewed in terms of larval dispersal and movement of adults among habitats. Many marine organisms produce larvae that are carried by ocean currents, so maintenance of existing systems and reestablishment of those that have been damaged is often reliant on larval dispersal that originates from distant locations. The length of time spent dispersing on ocean currents differs from species to species, but can be anywhere from minutes to months. Thus, larval dispersal time must be taken into consideration when setting MPA size and constructing MPA networks. Current guidelines suggest that MPAs approximately 20 km in diameter and spaced 20-100 km apart will accommodate both short- and long-distance dispersers of a wide range of target species (reviewed by Keller et al. 2008). Further research is needed, however, to better define dispersal direction and distance for marine organisms. Doing so will allow refinement of these general MPA size guidelines.

In addition to the movement of larval and adult fishes and invertebrates, linkages among habitats often include functional connections that are vital for maintaining ecosystem integrity. For example, salt marshes export nutrients and biomass that are used by organisms occurring offshore; coral reefs provide mangroves and seagrasses with protection from wave erosion; and mangroves buffer coral reefs and seagrasses from siltation. Functional dependencies highlight the necessity of protecting entire ecological units (e.g., mangroves to seagrasses to coral reefs). Unfortunately, setting aside entire ecological units is often not possible due to competing priorities for ocean uses.

Recognition of the need to address global temperature increases in marine resource protection has been spurred by the observation that rising ocean temperatures are resulting, as noted earlier, in an uptick in the frequency and severity of coral bleaching events. In places such as the Maldives and Palau, bleaching has essentially destroyed 50% or more of the reefs. The Australian government has taken the lead in managing for climate change in reef systems by developing the Great Barrier Reef Climate Action Plan 2007-2012 (http://www.gbrmpa.gov.au/). This five-year plan is built around four objectives that will make the Great Barrier Reef (GBR) more resilient to climate change. First, targeted science will furnish knowledge for improving reef resilience and for helping reef-based industries and regional communities adapt to changes. Second, reef resilience will be maximized by managing locally to reduce the impact of regional-scale stressors (e.g., modifying water quality targets and fishing practices) on the ecosystem. Third, social and economic resilience will be enhanced by guiding local governments and other organizations dependent on the resources of the GBR through the process of adapting to global change. Finally, efforts will be implemented to enhance awareness of the effects of global change on the GBR and to encourage individuals, communities, organizations, and industries to reduce greenhouse emissions. This plan has been lauded as a model for managing MPAs in an era of global change (Keller et al. 2008).

With the more recent recognition of the harmful effects of ocean acidification on marine organisms, efforts to develop MPA management strategies around this issue are in their infancy. Within the past year the Sanctuary Advisory Councils of the Gulf of the Farallones, Monterey Bay, Olympic Coast, and Cordell Bank National Marine Sanctuaries passed resolutions recognizing ocean acidification as a significant threat to the long-term health of sanctuary resources. These Advisory Councils recommended that NOAA institute new research, monitoring, education, and outreach activities to mitigate the effects of ocean acidification within all west coast sanctuaries. The actions taken by these Sanctuary Advisory Councils have stimulated similar discussions and calls for action in other U.S. marine sanctuaries, most recently in the Florida Keys and Gray's Reef. In some instances, through collaborations with scientists from universities as well as other organizations, data gathering has already begun. For example, efforts to monitor CO_2 and pH have been initiated in the Olympic Coast, Gray's Reef, and Gulf of the Farallones, and tests of coral growth rates in relation to carbonate chemistry are being carried out in the Florida Keys National Marine Sanctuary. These recent actions and activities suggest that MPAs will play a prominent role in uncovering the impact of ocean acidification on marine ecosystems.

While the exact environmental conditions that will result from global change are uncertain, it is clear that MPAs make, and will continue to make, an important contribution to understanding the impacts of global change on marine ecosystems. One of the major advantages of MPAs is that they are at least partially buffered from the detrimental effects of local stressors. This feature makes them ideal for deciphering the effects of global change on ecosystems. In some instances the possibilities for detecting global change effects have yet to be fully realized (Figure 4). Furthermore, the infrastructure for monitoring physical factors—such as temperature and dissolved oxygen—that have been in place for many years in some MPAs elevates the role of MPAs to that of "sentinel" sites, where early changes in environmental conditions might be detected. In sum, MPAs are not only areas set aside to preserve biodiversity, but also dynamic sites where research and management are combining and adapting to inform future policy with regard to management of oceanic resources under the influence of environmental change, which is unprecedented in modern times.

Figure 4. Sponge landscape at Grays Reef National Marine Sanctuary off the Georgia coast. The two species on the left, *Ptilocaulis walpersi* (red) and *Smenospongia cerebriformis* (purple/black) are considered temperate and the one on the right, *Axinella waltonsmithi* (yellow) tropical. Grays Reef sits at the convergence of tropical and temperate water masses and may be a sentinel site for detecting northward progression of species under global climate change.

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PHOTO CREDITS

Page 35: Table 1 reprinted and updated from Keller et al. (2008)

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NATIONAL ESTUARINE RESEARCH RESERVES AS SENTINEL SITES

The NERRS—a network of 27 estuarine reserves—offers teachers the opportunity to educate students about estuaries using near real-time and archived data collected through its System-Wide Monitoring Program (SWMP). SWMP measures short-term variability and long-term changes in coastal ecosystems, provides valuable long-term data on water quality and weather at frequent time intervals, and establishes a baseline of environmental conditions throughout the reserve system.

The 27 National Estuarine Research Reserves (NERRS) are uniquely positioned to serve as sentinel sites to observe the impacts of climate change on the coasts. With a robust monitoring infrastructure already in place, many Reserves are now directing their research effort to understand what happens as sea levels rise. Scientists are watching for changes in the ranges and migration patterns of plants and animals as water inundates more land areas, salt water intrudes into formerly freshwater habitats, and air and water temperatures increase.

Using the scientific findings of research in the Reserve System, many reserves also are gearing their Coastal Training Programs to help municipal and county planners and others understand how climate change will specifically impact their communities. This will help communities to begin addressing those impacts through zoning, infrastructure, and coordination in order to adapt to climate change. For more information about the National Estuarine Research Reserve Program, visit: www.estuaries.gov and http://nerrs.noaa.gov/.

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Seabirds as Indicator Species of Global Climate Change

The Cassin's auklet lives within the California Current Ecosystem, which is part of the North Pacific Gyre.

The Cassin's auklet is a seabird that spends the majority of its life in the open ocean. In the spring, these tiny birds find rocky shores in the Pacific to lay a single egg and care for chicks. The Gulf of the Farallones National Marine Sanctuary is an important breeding area for this species. Adult auklets feed their chicks with krill, tiny shrimp-like invertebrates that are an important component of marine food webs. In 2005 and 2006, scientists observed that parents abandoned 100% of the eggs laid on Southeast Farallon Island, resulting in a complete breeding failure—something that had not occurred in 37 years of observations. Previous partial breeding failures have been associated with the timing of El Niño, which has caused variations in zooplankton biomass (e.g., krill), reduced primary productivity, weather extremes, and warmer ocean temperatures. The exact mechanism that resulted in complete breeding failures in 2005 and 2006 remains unknown. Auklets depend on a seasonal "upwelling" cycle that brings cold, nutrient-rich waters from the ocean depths to the surface, replenishing the California Current ecosystem's nutrient supply. Changes in West Coast climate patterns may have caused a delay in this upwelling. Weak winds and currents likely left the Gulf of the Farallones without krill, eliminating the primary source of food for auklets to feed their chicks. Although auklet populations are recovering now, the increased occurrence and severity of breeding failures indicate the sensitivity of this species to abrupt changes in climate patterns, which are predicted to increase with global climate change. Scientists continue to study these seabirds as potential indicators of climate change.

Activity: Architects of Seamounts

FOCUS

Morphology and ecological function in habitat-forming, deep-sea corals

GRADE LEVEL

7-8 (Life Science)

FOCUS QUESTION

How does the physical form of deep-sea corals contribute to their ecological function?

LEARNING OBJECTIVES

Students will:

- describe at least three ways in which habitat-forming, deep-sea corals benefit other species in deep-sea ecosystems
- explain at least three ways in which the physical form of habitat-forming, deep-sea corals contributes to their ecological function
- explain how habitat-forming, deep-sea corals and their associated ecosystems may be important to humans
- describe and discuss conservation issues related to habitat-forming, deep-sea corals

MATERIALS

- Images of seamounts and deep-sea corals (see "For More Resources" for websites to access these)

AUDIO/VISUAL MATERIALS

- Copies of images of seamounts and deep-sea corals

TEACHING TIME

- One or two 45-minute class periods, plus time for student research

SEATING ARRANGEMENT

- Classroom style or groups of 3-4 students

MAXIMUM NUMBER OF STUDENTS

30

BACKGROUND INFORMATION

Seamounts (also called "guyots") are undersea mountains that are generally thought to be the remains of underwater volcanoes, often with heights of 3,000 m (10,000 ft) or more. There are an estimated 30,000 seamounts in all of the earth's oceans, but only a few hundred have been visited by explorers, and far fewer have been intensively studied. Volcanoes that can form seamounts are often associated with the movement of the tectonic plates that make up the earth's crust. Where these plates move apart (for example, along the mid-ocean ridge in the middle of the Atlantic Ocean) a rift is formed, which allows magma (molten rock) to escape from deep within the earth and harden into solid rock known as basalt. Where tectonic plates come together, one plate may descend beneath the other in a process called subduction, which generates high temperatures and pressures that can lead to explosive volcanic eruptions (such as the Mount St. Helens eruption which resulted from subduction of the Juan de Fuca tectonic plate beneath the North American tectonic plate). Volcanoes can also be formed at hotspots, which are thought to be natural pipelines to reservoirs of magma in the upper portion of the earth's mantle.

In the late 1960s, biologists searching for new commercial fishing grounds discovered that seamounts have high biological productivity compared to surrounding ocean waters, and provide habitats for a variety of plant, animal, and microbial species many of which were previously unknown. Deep-sea corals were often conspicuous, and provide essential habitat for other organisms in seamount ecosystems. Seamounts and plateaus near Australia and New Zealand were found to have large populations of deep-water fish with firm, tasty flesh. One species, the orange roughy (*Hoplostethus atlanticus*) is now common in North American markets. But fish stocks on seamounts were quickly diminished by commercial fishing vessels. Some studies report that deep-water trawlers have reduced orange roughy populations by as much as 90%. In addition, bottom trawling severely damages entire bottom communities: trawling is known to have removed 85% of the living cover from some seamounts (Malakoff 2003). In February 2004, concern for this large-scale destruction of virtually unexplored ecosystems led 1,136 scientists from 69 countries to release a statement calling for governments and the United Nations to protect deep-sea coral and sponge ecosystems. This same concern has stimulated scientific research on seamounts. The few existing surveys of seamounts suggest that many seamount species are endemic (found on only one or a few adjacent peaks). Recent research has shown that obscure, bottom-dwelling species may contain powerful drugs that directly benefit humans. On some seamounts, up to half the fishes and invertebrates are estimated to be unique. Seamounts may serve as "stepping stones" that allow other species to expand their ranges and may also help individuals of some species migrate over long distances.

In this activity, students will research deep-sea corals, and draw inferences about how their morphology contributes to their ecological function in seamount ecosystems.

LEARNING PROCEDURE

Explain that seamounts are the remains of underwater volcanoes and are islands of productivity compared to the surrounding environment. Tell students that expeditions to seamounts often report many species that are new to science and many that appear to be endemic to a particular group of seamounts.

You may want to show images of seamount communities from http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean .html. Point out deep-sea corals, and tell students that these animals are an important part of seamount ecosystems.

Assign students or student groups one of the following families of habitat-forming, deep-sea corals:

- Corallidae
- Isididae
- Paragordiidae
- Primnoidae
- Antipathidae
- Oculinidae
- Caryophylliidae
- Stylerasteriidae

Tell students (or student groups) that their assignment is to research their assigned family and prepare a report that includes:

(a) the taxonomic position of the family (phylum, class, order);

(b) a physical description of corals included in the family (appearance and type of skeletal structure);

(c) depth range over which the corals occur;

(d) ways in which corals in the family provide and modify habitat for other species;

(e) how the physical form of the corals contributes to their function in the ecosystem;

(e) ways in which these corals or associated species may be important to humans; and

(f) management and conservation issues.

Some websites that may be useful for students' research are listed under "For More Resources."

1. Lead a discussion of students' research results. The following points should emerge during this discussion: Taxonomy:
    - Corallidae- Phylum Cnidaria, Class Anthozoa, Subclass Alcyonaria, Order Gorgonacea
    - Isididae- Phylum Cnidaria, Class Anthozoa, Subclass Alcyonaria, Order Gorgonacea
    - Paragordiidae- Phylum Cnidaria, Class Anthozoa, Subclass Alcyonaria, Order Gorgonacea
    - Primnoidae- Phylum Cnidaria, Class Anthozoa, Subclass Alcyonaria, Order Gorgonacea
    - Antipathidae- Phylum Cnidaria, Class Anthozoa, Subclass Zoantharia, Order Antipatharia
    - Oculinidae- Phylum Cnidaria, Class Anthozoa, Subclass Zoantharia, Order Scleractinia Caryophylliidae- Phylum Cnidaria, Class Anthozoa, Subclass Zoantharia, Order Scleractinia
    - Stylerasteriidae- Phylum Cnidaria, Class Hydrozoa, Order Stylasterina
2. Deep-sea corals are found off all U.S. coasts, including Alaska and Hawaii.
3. Radiocarbon dating has established that some coral colonies are 10,000-12,000 years old (around the end of the last Ice Age).
4. Two-thirds of known coral species live in deep, cold water and are suspension feeders.
5. The majority of deep-sea corals have not been located; very few deep-sea coral reefs have been intensively studied.
6. Deep-sea coral colonies may host hundreds of other organisms (e.g., more than 2,000 individual animals and hundreds of species, including worms, crabs, shrimp, and fishes were found in a small coral colony with a head the size of a basketball).
7. Deep-sea corals provide multiple benefits to other species, including shelter, protection from predators, nursery areas, reduction of strong currents, and feeding areas.
8. The branching growth form of deep-sea corals contributes to their ecological function by providing numerous small spaces within the coral colonies that serve as sheltered areas in which other organisms may live (you can illustrate this effect by constructing a Sierpinski triangle, available at: http://coralreef.noaa.gov/education/educators/resourcecd/lessonplans/resources/seamount_archi_lp.pdf). The premise is that repeatedly dividing a fixed space produces an infinite series of increasingly smaller spaces that in nature are potential habitats for a wide variety of organisms.
9. The branching growth form of deep-sea corals also increases the surface area available to other organisms (particularly microorganisms).
10. The branching growth form of deep-sea corals reduces the force of strong currents that are often found in the vicinity

of seamounts, making it possible for more delicate species to live in seamount communities.

11. Deep-sea coral reefs provide essential habitat for many commercially important fish species, including red porgy, amberjack, snappers, groupers, and orange roughy.

12. Besides supporting commercial fisheries, deep-sea coral communities may also contain other species that can provide new pharmaceuticals; recent research has discovered a variety of deep-sea, bottom-dwelling invertebrates that produce powerful drugs that can be used to treat cancer, inflammatory diseases, and heart disease.

13. Skeletons of deep-sea corals contain records of climate change over thousands of years.

14. Destructive fishing gear, particularly bottom trawls, is one of the greatest threats to deep-sea coral ecosystems. Areas where an extensive amount of deep-sea coral is known to have been destroyed by trawling include Canada, Scotland, Norway, Australia, New Zealand, and the east coast of the United States.

THE BRIDGE CONNECTION

Click on "Ocean Science" in the navigation menu to the left, then "Ecology," then "Coral" for resources on corals and coral reefs: www.vims.edu/bridge/

EVALUATION

Written reports prepared in Step 2 provide opportunities for assessment.

FOR MORE RESOURCES

- NOAA Coral Reef Conservation Program website on Deep Sea Corals:
  http://coralreef.noaa.gov/deepseacorals/

- Article about scientists' call for protection of deep-sea coral ecosystems:
  http://www.terranature.org/deepsea_coral.htm

- Text of scientists' statement on protecting the world's deep-sea coral and sponge ecosystems:
  http://www.terranature.org/trawlingScientists_ban.htm

- Article, "Deep Sea Corals: The Cradle of Sea Life":
  http://www.savecorals.com/news/FS_cradle_of_life.pdf

- Malakoff, D. (2003). Deep-sea mountaineering. *Science* 301:1034-1037. (Article on seamounts and deep-sea coral communities.)

- Ocean Explorer photograph gallery:
  http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean.html

- Project Oceanica website, with a variety of resources on ocean exploration topics:
  http://oceanica.cofc.edu/activities.htm

- U. S. Geological Survey Open-File Report 01-154 "Sea-Floor Photography from the Continental Margin Program":
  http://pubs.usgs.gov/of/of01-154/index.htm

- Digital archive of seamount maps:
  http://www.earthref.org/databases/SC/main.htm

- Compendium of seamount-related research:
  http://seamounts.sdsc.edu/

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science
- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science
- Structure of the earth system

Content Standard F: Science in Personal and Social Perspectives
- Populations, resources, and environments
- Science and technology in society

FOR MORE INFORMATION

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CREDIT

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