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Module 4: Resilient MPAs and MPA Networks

Section 1: Representation and Replication

Learning Objectives

By the end of this lesson you will be able to:

- Identify the three factors of representation to consider and account for in planning MPAs
- Describe the reason for replication and several of the guiding principles to use when applying replication to MPA design

Background

Representation focuses on ensuring that all ecosystems and habitats within the region are represented in the MPA network. Representation at the habitat scale assumes that by representing all habitats, most elements of biodiversity (species, communities, physical factors, etc.) will also be represented in the network. Biodiversity changes locally, regionally, and with latitude. To address the changes in biodiversity across space, each MPA should be carefully placed to capture linked habitats, and to include the diversity of characteristics/conditions of the area. In addition to the biological characteristic of an area, the physical factors across an area need to be represented within the network of MPAs. This helps to build in the resilience by including a variety of conditions that may confer resilience.

When assessing representation for MPA network design, three universal factors should be considered and accounted for in the planning:

- Biodiversity composition: each habitat supports a unique community, and most marine animals use more than one habitat during their lives.
- Biogeographic structure: the environmental/latitudinal gradients in habitats and species composition that should be represented.
- Ecosystem integrity: maintenance of the ecological processes of the system is as important as representing all habitats.

Biodiversity Composition

MPAs should contain many different reef zones and habitats to maintain a full complement of biodiversity, and a steady, varied supply of larvae to replenish damaged areas and to replace dead or emigrated organisms.

Different reef types, depths, and zones within reefs are characterized by different coral assemblages, and different responses to temperature stress and bleaching. There are different species of corals and community types found in shallow lagoons, reef flats and reef crests. Others are found down the reef slope, and may only occur deeper than ~20 meters. Dominant corals and coral diversity differ in each assemblage. For example, sheltered reefs may have dense overlapping colonies of staghorn coral *(Acropora)* or large whorls of leafy corals *(Montipora, Pachyseris, Echinopora)* that are aesthetically pleasing, but have few species. Such reefs may be valuable for tourism, but are less so for conserving a representative range of biodiversity. They also tend to be more susceptible to bleaching.

To identify representative and unique habitats, a simple multidimensional classification of habitat, including, but not limited to, depth, exposure, substrate, and dominant flora and fauna is essential in MPA design. In practice, three categories of habitats should be considered for inclusion in coral reef MPAs to attain adequate representation:

1. Coral habitats
2. Contiguous habitats (i.e., submerged, intertidal, or above water)
3. Habitats linked across far distances

Biogeographic Structure

To address the biogeographic structure of the area, the reef type and major reef zones of each bioregion should be protected and geographically represented (e.g., at different latitudes) to reduce potential threats at each site. The MPA should aim to capture the onshore-offshore or habitat-habitat ontogenetic (or life-stage) shifts of species. For example, the MPA should capture the gradient from mangrove to reef as fish move from larval to adult stages, respectively.

Ecosystem Integrity

Ecosystem integrity refers to the degree to which a given area (potential MPA site) functions as an effective, self-sustaining ecological unit. Distinct processes and physical attributes give rise to different coral reef communities; for example, seaward reefs endure greater wave stress than back reef lagoons. These distinct processes are reflected in variations of coral assemblages and zonation patterns. The protection of ecosystem processes is equally important as the protection of all habitats. Representation of physical factors of the area helps to build resilience into the MPA network. MPAs should be placed in areas that capture all major physical characteristics including:

- Exposure
- Energy regimes
- Wave energy

- Weather patterns
- Eddies
- Strong currents

<u>Replication</u> is the inclusion of multiple samples of habitat types in MPAs and networks to spread the risk of large-scale events, such as bleaching. Replication of protected resistant and resilient coral communities at multiple sites increases the probability that some reefs will survive bleaching, and helps the recovery of affected areas.

MPA networks are most effective when each habitat type is represented in more than one MPA. The goal of representation could be met by having only one MPA for each biodiversity element; however, if the habitat is destroyed in the one MPA, representation of that diversity would be compromised, as there would be nothing under protection. Replication provides a buffer against catastrophic loss of an MPA.

To spread the risk of damage or extinction by ensuring that habitat types are replicated in the network, the following guidelines are recommended:

- At the very minimum, three replicates of habitat type should be included, but more is always better. The number of replicates of each habitat type must be a balance between ensuring representation and ensuring effective monitoring and enforcement.
- For large biogeographic areas (100s–1000s km), the MPA should conserve a representative example of each bioregion.
- For smaller areas (1 km–100s km), the MPA should include reef types and major reef zones, which can serve as proxies (or substitutes) for community types.

Replicate MPA sites enable the dispersal of marine species between areas. Many marine species follow a stepping stone model, in which populations exchange larvae with adjacent populations. Replicate MPAs can be designed to accommodate dispersal patterns of species, and facilitate connectivity between the sites. Spacing considerations will also influence fulfilling the stepping stone role of MPAs.

Replication of MPAs also provides analytical power for management comparisons. With more than one MPA, reference, or control sites, can be incorporated into the monitoring program to evaluate the biological changes in and between each of the MPAs. This type of comparison facilitates adaptive management.

Activity: Part 1

Application Exercise: Reef Classification

Goal: To develop a classification map of the major reefs types and zones for your region

Purpose: The reef classification map will be used in the next exercise to identify representative and resilient reefs and replicates for selection as MPAs/zones. It can also be used to develop the sampling design for a rapid response plan for a major coral bleaching.

Group Exercise

Instructions:

1. Delineate major reef types (e.g., atolls, barrier, fringing, patch) and zones (e.g., fore reef, back reef, spur and groove) on your map
2. Identify three factors that explain major coarse divisions in coral reef communities across your region (e.g., wave energy, ocean circulation, isolation)
3. Identify three factors that explain finer level differences (e.g., depth, salinity, turbidity)
4. Apply these factors to differentiate among the reef types and zones on your map
5. Draw divisions on your map and note the reasons.

This should be done using maps provided (or that you brought with you). Use markers to draw boundaries, make notes, or highlight special features on your map. Record your decision-making process in the notes section so that you may return to this activity in the future.

Output: Country map with reef areas classified

On-the-Web

Reef Resilience Toolkit:
http://reefresilience.org/Toolkit_Coral/C5a0_Representation.html

Publications and References

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Spalding, M.D., Fox, H., Allen, G.R., Davidson, N., Ferdana, Z.A., Finlayson, M., Halperin, B.S., Jorge, M.A., Lombana, A, Lourie, S.A, Martin, K.D., McManus, E., Molnar, J., Recchia, C.A., Robertson, J. 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. BioScience 7: 573-583: http://www.bioone.org/doi/abs/10.1641/B570707

Section 2: Managing Critical Areas

Learning Objectives

By the end of this section, you will be able to:

- Identify representative and resilient reefs and replicates for selection for MPAs/zoning schematic (using information developed in the reef classification exercise).
- List types of biologically and ecologically significant areas to consider in MPAs
- Identify critical areas to consider in MPA design
- List resistant and resilient factors in coral reefs

Background

It is important to protect communities and systems that are naturally positioned to survive global threats. These areas serve as refuges to secure and maintain sources of larvae to replenish damaged areas. Protection of areas that are known to be resistant or resilient to threats, including bleaching events or other localized impacts, is also important. This section is intended to highlight the importance of considering special biological and ecological elements of a coral reef system.

Ecologically Significant Areas

Biologically and ecologically significant areas include:

- Sources of larvae and spawning aggregations;
- Nursery and breeding grounds of fish and other marine organisms;
- Developmental and feeding habitats; and
- Migration corridors
- Sea turtle nesting areas

Unique or Vulnerable Habitats

The presence of rare, endangered, relict, restricted-range species, and populations with unique genetic composition should be considered for MPA placement. Including unique places in the network will ensure that the network is comprehensive and adequate to protect biodiversity and known sensitive or unique areas. Some marine habitats are more vulnerable to natural and human impacts than others. These habitats include:

- coral reefs
- deep-sea coral communities
- oyster reefs
- salt marshes
- seagrass beds
- mangroves

Resistant Characteristics

Representation of reef communities or coral types that display resistance to bleaching is a vital component of an MPA, and should be afforded high levels of protection, and should be buffered within larger management areas. If a coral reef is resistant, it is more likely to withstand environmental fluctuations or unexpected catastrophes. These resistant communities can play a critical role in reef survival, by providing the larvae to recruit and enable recovery of affected areas.

Resistance Factors in Coral Reefs

Determinants of resistance to bleaching have been identified in some coral communities and species. For example, coral communities that are exposed to extreme conditions on a regular basis (e.g., shallow water or intertidal corals) maintain a higher resistance to bleaching than other non-exposed corals. The following list of resistance factors in coral communities should be considered in any MPA design.

- Localized upwelling of cool water
- Areas adjacent to deep water
- Regular exchanges (cooler waters replace warm water)
- Permanent strong currents (eddies, gyres, tides)
- Wind topography (narrow channel, peninsulas and points)
- High wave energy
- High tidal range
- Shade (from high land profile, undercut coastlines or reef structure)
- Steep slope from coral assemblages and structure
- Presence of naturally turbid water
- Cloud cover
- Exposure to elevated water temperatures (warmer waters in shallow back-reef lagoons)
- Frequent exposure and emergence at low tide
- High diversity and abundance of reef species
- Wide range of coral colony sizes and species distribution
- History of coral survival after bleaching

Considering the above mentioned resistance factors, the following guidelines are recommended:

1. Survey MPAs and their adjacent areas for the presence of environmental factors that cause bleaching resistance, and identify coral communities protected by them.

2. For resistant coral communities *inside* established MPAs, consider securing high levels of protection for them by revising zone boundaries, or establishing special zones to encompass these sites.
3. For resistant coral communities *outside* established MPAs, consider extending MPA boundaries to incorporate these sites, if feasible, or creating new MPAs to include them.

<u>Resilient Characteristics</u>

Representation of coral reefs or their components that demonstrate resilience to environmental fluctuations or threats (e.g., bleaching, hurricane, etc.) need to be included in zones with high levels of protection, and should be managed to maintain conditions that facilitate successful coral recruitment and recovery. To maximize both strong and reliable recruitment of all species within the community, and the likelihood that a portion of the recruits will enter surrounding areas, it is important that the MPA includes resilient features.

<u>Resilience Factors in Coral Reefs</u>

The following list of resilience factors in coral reef systems should be considered in any MPA design.

- Availability and abundance of local larvae recruits
- Evidence of recruitment success
- Diversity and abundance of different coral reef taxa, especially high herbivore densities and representative community structure
- Low abundance of bioeroders, corallivores, and diseases
- Effective management regime supported by legal framework, participation and enforcement
- Larval transport and connectivity by currents
- Concentration of larval supply

Considering the above mentioned resilient factors, the following guidelines are recommended:

1. Survey MPAs and their adjacent areas for the presence of environmental factors that cause bleaching resistance and identify coral communities protected by them. See Florida Keys and Mesoamerican Reef Case Studies as examples in the R2 Toolkit.
2. For resilient coral communities *inside* established MPAs, consider securing high levels of protection for them by revising zone boundaries or establishing special zones to encompass these sites.

3. For resilient coral communities *outside* established MPAs, consider extending MPA boundaries to incorporate these sites, if feasible, or creating new MPAs to include them.

On-the-Web

Reef Resilience Toolkit:
http://reefresilience.org/Toolkit_Coral/C5b0_IncludeCriticalAreas.html

Link to recent SST map:
http://www.ssec.wisc.edu/data/sst/latest_sst.gif
http://www.osdpd.noaa.gov/PSB/EPS/SST/climo.html

Link to real-time currents:
http://www.oscar.noaa.gov/datadisplay/index.html

The Angle of the Sun's Rays:
http://www-istp.gsfc.nasa.gov/stargaze/Sunangle.htm

Society for the Conservation of Reef Fish Aggregations
http://www.scrfa.org

Publications and References

The Science of Marine Reserves A Literature Review of Biophysical Guidelines for MPA Network Design and Implementation http://www.piscoweb.org/publications/outreach-materials#booklets

Establishing Resilient Marine Protected Area Networks—Making it Happen

West, J.M., and Salm, R.V. 2003. Resistance and resilience to coral bleaching: implications for coral reef conservation and management. Conservation Biology 17(4): 956-967.

Section 3: Incorporating Connectivity

Learning Objectives

By the end of this lesson, you will be able to:

- Identify the main aspects of connectivity to consider in MPA design
- Describe what is meant by connectivity between adjacent habitats and between distant habitats
- Identify ways to consider larval dispersal and adult population movement patterns into MPA design

Background

A network of MPAs should maximize connectivity between individual MPAs to ensure the protection of ecological functionality and productivity. In this training, connectivity and ecological linkages include:

- Connections of continuous or adjacent habitats such as coral reefs and seagrass beds, or among mangrove and seagrass nursery areas and coral reefs
- Connections through regular larval dispersal in the water column between and within MPA sites.
- Regular settlement of larvae from one MPA to inside another MPA
- Marine life adult movements in their home range, from one site to another, or because of spillover effects from MPAs

It is important to take a system-wide approach in the design of MPA and MPA networks, one that recognizes patterns of connectivity within and among ecosystems (including the linkages among coral reefs, seagrasses, mangroves, watershed, etc.), as well as the connectivity between two populations. The strength of connectivity between locations depends on the abundance and fecundity of source populations, how far larvae disperse before settling to adult habitat, spawning sites and movement patterns of adults, as well as oceanographic effects (e.g., current patterns and retention features).

<u>Adjacent Habitats</u>

Ocean habitat types are connected through the movements of juvenile and adult organisms and through the transfer of materials and nutrients. Adjacent habitat systems are linked through the flow of matter, energy, and organisms. The following adjacent habitat types should be considered in the design of the MPA network:

Reef Flats
Back-reef Lagoons

Seagrass Beds and Sand Flats
Mangroves
Beaches and Dunes

Distant Habitats

Coral reefs are linked to distant areas by dynamic processes (e.g., currents, rivers, and species movements) and may be influenced by activities occurring in remote areas. Distant sources of stress, such as deforestation and development in a watershed, can cause erosion and release sediments that smother reefs. The distant sources of stress may be difficult to identify from a coral reef management perspective, and even more difficult to control.

While watersheds are not obvious or easy candidates to include in coral reef MPAs, they may be connected to reefs by streams and coastal currents. Damaging activities in a linked watershed will need to be controlled by a "ridge to reef" approach to MPA planning, or by coastal zone management approaches that complement MPA planning and management.

Larval Dispersal

Many fish, invertebrates and corals release great numbers of eggs and young into the open ocean. The pelagic larvae can remain floating or moving through ocean currents for hours, days, or even months, traveling distances of 1-1000s of km prior to settling. The distance and the patterns of larval dispersal are influenced by several factors which act synergistically over the pelagic larval duration including: larval behavior and duration, food resources, predators encountered, and currents.

When species-specific larval dispersal data are limiting, dispersal information for a broad range of taxa can be used. Dispersal of a particular species is not as important for the MPA network design as the sum of the larval dispersal for all the species of concern. Generally, species in a community display a range of larval dispersal distances that can be used as a guideline for MPA size and spacing in order to accommodate the dispersal distances of either focal species or the broadest range of species.

The following MPA design principles are recommended to address larval dispersal:

- To compensate for constantly changing ocean conditions, which have impacts on larval dispersal patterns, MPAs should be located in a wide variety of places in relation to the prevailing currents.
- In areas where currents are complex (e.g., eddies or reverse flows), an even spread of MPA locations is recommended.

- In areas where currents are strongly directional, MPAs sited in upstream locations will be more likely to support recruitment to the rest of the management areas than those in downstream locations.
- A network of MPAs linked to each other by prevailing currents will facilitate the recovery of damaged areas, and the maintenance of biodiversity through larval exchange.

<u>Adult Movement Patterns</u>

The movement patterns of adult species are important to consider in MPA design. How much protection an MPA affords a species depends (to some degree) on movement habits and distances of the individual (both as adult and larvae).

If adults move widely, the ocean neighborhood is large and diffuse. If adults are sessile, then the ocean neighborhood might be small and distinct.

The following MPA design principles are recommended to address adult movement patterns:

- Gather information on target species adult movement distances and patterns. Information about the species' ocean neighborhood can provide insights to help guide MPA size and spacing. For example, the size of the MPA can be based on adult neighborhood scales of highly fished species to ensure that at least some adults remain protected during the adult life stage.
- Ultimately, an MPA that accommodates species with the largest adult movement patterns should protect species with smaller adult movement distances as well. For example, MPAs designed to ensure self-seeding for species that move up to 100 km as adults should be sufficient for self-seeding of species that move only 10 km as adults.

On-the-Web

Reef Resilience Toolkit:
http://reefresilience.org/Toolkit_Coral/C5c0_IncorpConnectivity.html

CCAR Real-Time Altimeter Data Group http://argo.colorado.edu/~realtime/gsfc_gom-real-time_ssh/

PISCO http://www.piscoweb.org/

Publications and References

Jones, G.P., Srinivasan, M. and Almany, G.R. 2007. Population connectivity and conservation of marine biodiversity. Oceanography 20(3):12

Kinlan, B.P. and Gaines, S.D. 2003. Propagule dispersal in marine and terrestrial environments: a community perspective. Ecology 84 (8): 2007-2020.

Managing Mangroves for Resilience
http://www.reefresilience.org/pdf/Managing_Mangroves.pdf

Palumbi, R.S. 2004. Marine reserves and ocean neighborhoods: The spatial scale of marine populations and their management. Annual Review of Environment and Resources 29: 31-68.
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Section 4: Size, Shape, and Spacing

Learning Objectives

By the end of this lesson, you will be able to:

- Describe the basic guidelines on sizing for MPAs
- Describe core-zones
- Identify the two main aspects of spacing that need to be considered in MPA design
- Describe the two components of shape to consider in the design of an MPA

Background

The size, shape and spacing of individual MPAs in an MPA network greatly influence the degree to which conditions in the wider environment affect the features of the MPA, and exchange of individuals between the MPA and adjacent environment. The three components of size, spacing, and shape should be considered in design of the MPA network to facilitate and promote connectivity between and within the MPA network.

Deciding how many, how large, and how far apart MPAs should be is a challenge. Ultimately, size, shape and spacing design of an MPA network will vary with the goals and objectives of the MPA, as well as the social and economic environment in which it is located. However, there are some general design guidelines on size, shape and spacing of each MPA that will help to ensure maximum benefits to individual MPAs within a larger MPA network

Size Matters

The size of an MPA should take into consideration the need for large populations to insure against catastrophes, as well as the patterns of connectivity. Even small sized MPAs can provide positive benefits, in terms of fish biomass, size and abundance, but a single, small MPA provides insufficient protection to large populations of many species. In general, bigger MPAs can protect more habitat types, more habitat area, larger populations of species, and a greater number of species in the ecosystem.

The ideal size of MPAs for biodiversity conservation will generally be larger than those planned for fish stock protection and enhanced recruitment. In terms of fisheries, as MPA size increases, the potential fisheries benefit from spillover and larval recruitment will increase, but only to a certain point, and only if those targeted species are protected. General MPA size principles that apply to the entire MPA network are provided in the following recommendations:

- Aim for 10-20 km in diameter, across MPA minimum width.

- In terms of biodiversity protection, fewer large MPAs are preferable to a greater number of smaller ones.
- To meet both fishery and conservation goals, intermediate sizes of MPAs, and a variation of sizes within a network may be ideal.
- Consider feasibility of management. A smaller MPA is easier to enforce, and the monitoring efforts are less demanding. Larger MPAs take longer to establish and implement, and require greater financial support.

No-take Areas

Coral bleaching events have demonstrated that replenishment is an important consideration for reef survival, regardless of the management objective. The effects of bleaching cannot be lessened by MPA zones, boundaries, regulations, or management efforts. Therefore, MPAs should be designed specifically to meet the requirements for reef survival. MPAs need to be large enough to be self-replenishing and sustainable. The optimal size of an MPA is designed around a strictly protected, no-take zone, or 'core zone', which encompasses sufficient target coral areas to be self-replenishing. To support self-replenishing MPAs, the following no-take zone guidelines are recommended:

- The no-take area should be selected to encompass a diverse range of reef habitats.
- The no-take area should be as large as possible to preserve a high diversity of reef biota.
- Large reefs may be self-replenishing, because their size allows portions of reefs damaged by bleaching, slumping (collapse of the reef slope), storm surges, freshwater flooding, or other stresses, to be replenished by recruits from undamaged parts of the same reef.
- To ensure self-seeding, the MPA should be as large as the mean larval dispersal distance of the target species.

Optimal Spacing

The exchange of larvae and adult organisms among MPAs is the fundamental biological rationale for MPA networks. To function as an effective network, the MPAs should be spaced to facilitate the connectivity between one another. Spacing of individual MPAs within the network is critical to maximize recruitment outside the MPAs. The design of the network of MPAs should: (1) accommodate the long distance dispersal of larvae; (2) capture the biogeographic range of variation in habitats and species.

Movement out of, into and between MPAs by adults, juveniles, larvae, eggs, or spores of marine organisms depends on their dispersal distance, and guides spacing aspects of MPA network design. In general, the lower the effective larval dispersal of a species, the closer the MPAs will have to be to provide benefits to unprotected areas. MPAs that are more closely spaced are more likely to be ecologically connected and serve to protect a greater number of species through movement of young and increased recruitment from other MPAs. Therefore, MPAs should be spaced appropriately to capture the broadest range of dispersal distances as possible.

MPA spacing is habitat dependent. Habitat distribution patterns should influence where the MPAs are placed and how they are spaced. Within an MPA network, what matters is not spacing to the next MPA, but spacing to the next MPA that offers suitable habitat for the target species (or range of target species). Based on the habitat distribution or larval dispersal of the target species, spacing between MPAs can be established.

In general, the following spacing guidelines are recommended:

- To facilitate dispersal and promote connectivity between MPAs, MPAs should be placed appropriately to capture the middle range of dispersal distances. It is recommended that MPAs should be placed within 10 - 20 km of one another to capture effective connectivity.
- MPAs should be spaced to capture the biogeographic range of variation in habitat and species.
- Variable spacing is better than fixed spacing when there are several small reserves rather than a few large reserves (as long as they are within this 10-20km range)

Shape Matters

There are two components of shape to consider in the design of an MPA: edge effects and enforceability.

Edge Effects : In the design of an MPA, it is important to consider the ratio of edge habitat versus core interior habitat, as the edges (or perimeter boundary line) of MPAs are often extensively fished, and therefore do not offer the same refuge to fish species as the interior protected areas do. Juvenile and adult spillover from the MPA is edge-dependent, and as the amount of edge of an MPA increases, faster export is expected, relative to the total protected area. It is important to **minimize edge habitat and maximize interior protected area.**

Enforceability: The shape of an MPA is also a critical factor in effective delineation and enforcement. A shape that allows for clear marking of boundaries for both resource users and enforcement personnel may increase effectiveness. MPAs with boundaries that conform to natural habitat edges offer fuller protection than MPAs with boundaries that cross reef habitat types and zones. However, the ease of compliance and enforcement capabilities need to be taken into account.

- MPAs should be contiguous, compact and easily delineated.

- Consider obvious, easy GPS reference points, such as landmarks and distinct habitat types.
- Regular MPA **shapes of squares or rectangles are preferable** because they can be delineated by lines of latitude and longitude, and therefore more easily identified by user groups.

On-the-Web

Reef Resilience Toolkit:
http://reefresilience.org/Toolkit_Coral/C5d0_SizeSpacing.html

Publications and References

Gaines, S.D., Gaylord, B., and Largier, J.L. 2003. Avoiding current oversights in marine reserve design. Ecological Applications 13(sp1): 32-46

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Section 5: Socioeconomic Criteria

Lesson Objectives

By the end of the lesson, you will be able to:

- Identify the main sectors that socioeconomic efforts tend to focus
- Describe ecosystem services and identify the four main groups of services
- List the ecosystem services that should be considered and how to measure them for MPA planning

Background

Social and economic criteria should always be considered when creating a resilient MPA network. The challenge is how to integrate requirements of natural systems with needs of the people who depend upon them. An effectively managed, resilient MPA network is one way to address this challenge. MPA creation can help move from single sector management to a more holistic approach, including human and ecosystem interactions, and cumulative impacts. This multiple-objective approach can create a foundation that transforms the way people address conflicts between the environment and the economy.

Although all social and economic factors, including the costs and benefits to humans and the environment, should be considered in creating an MPA network, the majority of efforts tend to focus on:

Tourism: Often a majority of income, especially in developing countries, comes from tourism. It is important to create tourism industries with limited biodiversity impacts, local knowledge that is used for tours and management, and buy-in from the local community to be stewards for their natural resources.

Fisheries: Commercial and some artisanal fishing can have the largest impacts, and be most impacted by MPA networks. Local fishers may have to learn new trades or fish with alternative gear to ensure their livelihoods are secure. Support and buy-in from the local community, stakeholders, and government is imperative to a successful and sustainable MPA network.

Other (climate change, ports/marinas, coastal development): Creating a successful resilient MPA network depends on accounting for the many effects of climate change, some of which are addressed in this toolkit. In addition, there will always be multiple uses in or near an MPA. Working with the community and multiple stakeholders to create a win-win situation for everyone is key.

Ecosystem Services

What are Ecosystem Services?

1. Humankind benefits from a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are defined as "ecosystem services" and include products like clean drinking water, and processes like the decomposition of wastes. The Millennium Assessment has identified four groups of ecosystem services: Provisioning (e.g., subsistence and commercial fisheries attained from healthy reefs)
2. Regulating (protection of beaches and coastlines from storm surges and waves)
3. Cultural (tourism and recreation)
4. Supporting (nursery habitats)

Ecosystem services are distinct from other ecosystem products and functions, because there is human demand for these natural assets.

As human populations grow, so do resource demands imposed on ecosystems and impacts of our global footprint. For many years, people have assumed that these ecosystem services are free and infinitely available. However, impacts of anthropogenic use and abuse are becoming more apparent, especially around coral reefs: oceans are being overfished, invasive species are extending beyond their historical boundaries, and deforestation is eliminating flood control around human settlements. Consequently, society is now realizing that ecosystem services are not only threatened and limited, but that the need to evaluate trade-offs between immediate and long-term human needs is urgent.

To help inform decision-makers, economic value is increasingly associated with many ecosystem services, and often based on the cost of replacing these services with human derived alternatives, such as installing a breakwater where the natural system that used to provide a barrier has been destroyed. The on-going challenge of prescribing economic value to nature is prompting shifts in how we recognize and manage the environment, social responsibility, business opportunities, and our future as a species.

What Services Should Be Considered?

Since there are many ecosystem services that benefit humans it is important to include them in management plans. These services have been well reviewed and defined in the Millennium Assessment, and the other links on this page.

Often the provisioning and cultural services of fisheries and tourism, respectively, are considered in MPA management plans. However, regulating and supporting services should also be reviewed, valued if possible, and represented in any resilient MPA network. A healthy reef will be able to provide multiple services to the community that depends on it; including the services the reef provides in management plans is one way to ensure reef health.

Measuring Ecosystem Services

There are many methods by which to measure ecosystem services. However, it should be noted that the values that are determined from these methods, whether in dollars, number of jobs, or tons of fish, should be kept in perspective and evaluated within the larger context of how they will contribute to reef health.

Using Ecosystem Services Information

Once services have been measured, or at least accounted for, managers can use this information to:

- Prioritize which areas should be protected/restored
- Balance between extractive and conservation uses
- Balance between sustainable harvesting and ensuring healthy reefs for biodiversity and tourism goals

On-the-Web

Reef Resilience Toolkit:
http://reefresilience.org/Toolkit_Coral/C5e0_Socioeconomic.html
Kimbe Bay Case Study: http://www.reefresilience.org/Toolkit_Coral/C8_Kimbe.html
NOAA Coasts: http://www.noaa.gov/coasts.html
Biodiversity of Economics: http://pdf.wri.org/cesardegradationreport100203.pdf
SOCMON: http://www.reefbase.org/socmon/default.asp?redirect=home_04

Publications and References

The Economics of Worldwide Coral Reef Degradation (links to many MPA papers):
http://pdf.wri.org/cesardegradationreport100203.pdf

Activity: Part 2

Application Exercise: MPA Design/Zoning

Purpose: Using information developed in the reef classification exercise, identify representative and resilient reefs and replicates for selection for MPAs/zoning schematic. This preliminary work can be used to begin the process of designation or consideration of zones in existing managed areas with stakeholders at your site(s).

<u>Group Exercise</u>
Instructions:
Based on the information you developed in the classification exercise and the criteria listed below, choose a portfolio of MPA sites for your country or zoning scheme for your site. This should be done using maps provided (or that you brought with you). Use markers to draw boundaries, make notes, or highlight special features on your map. Record your decision-making process in the notes section so that you may return to this activity in the future.

Step 1: Review criteria below to further describe your area

- Good example of reef or habitat type
- Good condition
- High biodiversity
- Low level of threat
- Survived bleaching
- Recovering well from bleaching mortality or disturbance
- High habitat complexity
- Replicates of the above at regular intervals (20 km where possible) by Latitude/Longitude

Step 2: Identify Critical Areas

Step 3: Choose a portfolio of MPA sites for your country or zoning scheme for your site using what you've learned about resilience and rules of thumbs for connectivity, critical areas, size, shape, spacing, and socioeconomic criteria

Step 4: Peer review your work within your group (if more than one country)– prepare to report back in a 30 minute poster session at end of exercise

Output: Country map with MPA or MPA network design/zoning scheme

Rules of Thumb Checklist for MPA/Network Design

Representation & Replication

- Good representation of habitat types, structure, function, physical conditions
- Minimum of 3 replicates of each habitat type/condition (classified area)

Critical Areas

- Inclusion of important nesting, breeding, and nursery grounds
- Inclusion of special areas (e.g., likely resilience/resistance to bleaching, ecologically sensitive areas)

Connectivity

- Inclusion of known 'source' areas
- Protection of habitat linkages (e.g., reef to seagrass to mangrove)

Size, Spacing, Shape

- 10-20 km diameter at minimum width
- Fewer large better than many small
- 10-20 km between core zones or MPAs
- Regular shapes easy to delineate and enforce (e.g., squares, rectangles, straight lines)

Socioeconomics

- Consider locations away from industrial areas or other high impact land use areas
- Consider existing activities that may be impacted or have negative impact on MPA (e.g., traditional use, commercial use, recreational use)
- Consider user conflicts to minimize future problems