CONNECTIVITY CONCEPT PAPER FOR UNDP/GEF
THE YELLOW SEA LARGE MARINE ECOSYSTEM PROJECT

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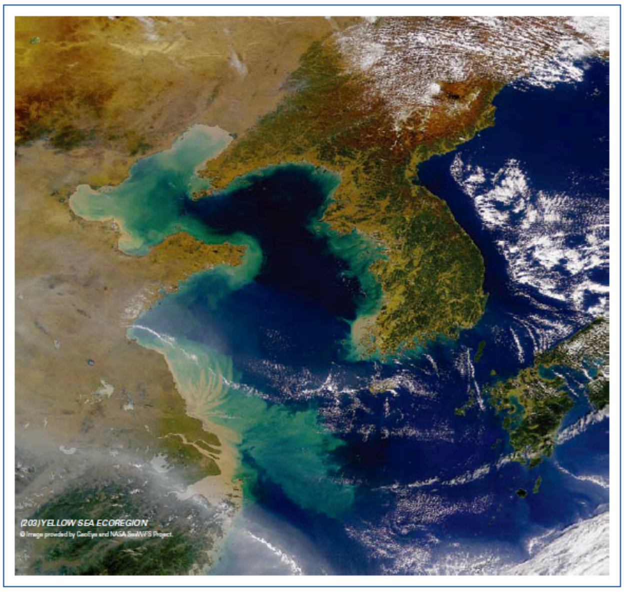

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Overview

It is widely known that MPA networks can greatly enhance MPA effectiveness because networks provide more protection than a set of individual, unconnected areas and they allow for management efficiencies. Biological or ecological networks are based on shared or complementary biological or oceanographic features that enhance each MPA's ability to meet ecological, biodiversity, fisheries and resilience goals. Social networks result in increased administrative effectiveness via unified management efforts, shared information, a sense of empowerment by those involved, and potentially increased political will. Management- based, institutional, or governance-based networks can increase political will, and provide consistency and potential cost savings in management strategies across the network. MPA networks, when effective can magnify the benefits of individual sites, protect large- scale processes, slow the loss of endangered marine species and restore depleted fisheries (IUCN 2008). **The purpose of this concept paper** is to provide a roadmap to MPA practitioners and associated working groups of the YSLME Phase II project to collaboratively establish a functional network of marine protected areas in the Yellow Sea Eco-region contributing with and taking into consideration the most up to date biophysical and oceanographic information available during a gathering, technical workshop and with regional research institution with capabilities for ecological modeling and analysis[1].

The objectives of the connectivity concept paper are to provide:

- Elements of scaling up from individual MPAs in the Yellow Sea Large Marine Ecosystem to networks of MPAs
- Identify the ecological benefits of MPA networks
- Understand the biophysical, elements and tools required to design ecologically connected and functional MPA networks
- Apply principles of designing biophysical MPA networks to the YSLME
- Recognize biophysical features in the Yellow Sea of MPAs that make them suitable for inclusion in an effective MPA network
- Taking into considerations for Large Scale MPA networks

Background:

The objective of the UNDP/GEF Yellow Sea Large Marine Ecosystem (YSLME) Project is to facilitate the ecosystem-based management and environmentally-sustainable use of the Yellow Sea and its watershed by reducing development pressure and promoting sustainable development of this densely populated, heavily urbanized, and industrialized semi-enclosed shelf sea ecosystem. To achieve this objective, the YSLME Project prepared a Transboundary Diagnostic Analysis (TDA) and regional

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[1] Note the information provided as background information is based on what the contracted consultant was provided or is available on line in many cases outdated or insufficient for a proper ecological connectivity analysis.

Strategic Action Programme (SAP). National Yellow Sea Action Plans (NSAPs) and demonstration activities of the SAP (UNDP/GEF 2009), management actions were also prepared. According to the TDA (UNDP/GEF 2007), nine major transboundary environmental concerns have been identified:

- Pollution and Contaminants;
- Eutrophication;
- Harmful Algal Blooms (HABs);
- Fishing Effort Exceeding Ecosystem Carrying Capacity;
- Mariculture Facing Unsustainable Problems;
- Habitat Loss and Degradation;
- Change in Ecosystem Structure;
- Jellyfish Blooms; and
- Climate Change-related issues

To address the above environmental issues, the YSLME SAP set regional management targets for environmental quality of the Yellow Sea, and the required management actions to achieve these targets by 2020. Based on the concept of the "ecosystem carrying capacity" (ECC), the SAP proposed the eleven targets and corresponding actions according to the services that the Yellow Sea ecosystem provides. The actions consists of both technical and institutional/legislative (governance) interventions. The targets primarily address a particular ecosystem service with the understanding that achievement of a target will also benefit other ecosystem services[2]. One of the assistance programs to implement SAP is UNDP/GEF/UNOPS project entitled Implementing the Strategic Action Programme for the Yellow Sea Large Marine Ecosystem: Restoring Ecosystem Goods and Services and Consolidation of a Long-term Regional Environmental Governance Framework, or the UNDP/GEF YSLME Phase II Project. The project was launched in July 2017. The identified ecosystem services of the YSLME are: a) Provisioning Services, b) Regulating Services, c) Cultural Services, and d) Supporting Services.

This Connectivity Concept paper for the YSLME supports specifically Outcome 4.1 titled 'MPA Network strengthened in the Yellow Sea' of under Action 10.2 of Target 11 'Maintenance of Habitats according to standards and regulations of 2007', to address 'Supporting Services'. It is expected that a series of activities leading to the expansion of the MPA system will take into account connectivity measured by the use of this concept paper.

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[2] The targets were set using measurable scientific understanding of 2007 with the understanding that under ecosystem-based management, scientific monitoring is essential to assess the impact of the management actions and management must be adaptive to respond to new knowledge.

Key citations related to Yellow Sea Large Marine Ecosystem Project

Mengtian C, Li P, and Shaoquan L (2015). Analysis of the Network of Protected Areas in China Based on a Geographic Perspective: Current Status, Issues and Integration; Sustainability, 7, 15617-15631; doi:10.3390/su71115617

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WWW Japan, KORDI, and KEI (2006)
Yellow Sea Ecoregion, a Global Treasure, a Global Responsibility;

WWW Japan, KORDI, KEI and YSLME (2008)
Biological Assessment Report of Yellow Sea Ecoregion; Ecological important areas for the Yellow Sea Ecoregion Biodiversity

Yunzhou Li, and David L. Fluharty (2017). Marine protected area networks in China: Challenges and prospects. Marine Policy 85(2017): 8-19

2. MPAs Networks in the Yellow Sea Large Marine Ecosystem

2.1 Rational for MPAs

Marine ecosystems are declining all over the world due to overfishing, runoff for nutrients and land-based pollutants, habitat degradation and climate change. These lead to ecosystem collapse along the coast and in the world's oceans. One way to stem the loss is by establishing and implementing marine protected areas (MPAs). The World Conservation Union defines an MPA as a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means to achieve long-term conservation of nature with its ecosystem services and cultural values. The Yellow Sea Large Marine Ecosystem (YSLME) Region has a core focus on expanding and effectively managing MPAs to support livelihoods and biodiversity and strong resilience against multiple pressures.

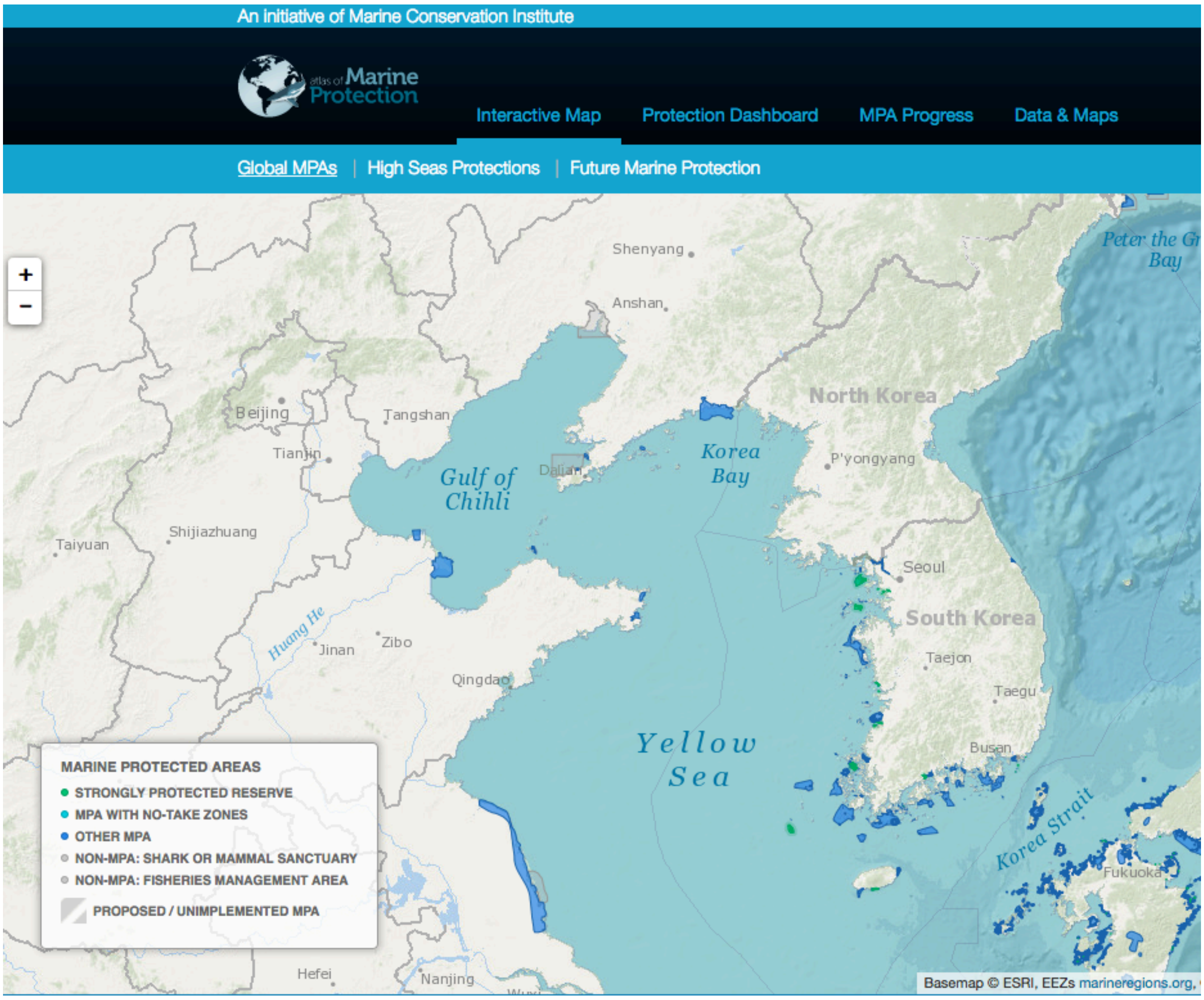


Fig. 1.1 From http://www.mpatlas.org/map/mpas/

2.2 Existing MPAs Networks in the YSLME

The Yellow Sea Large Marine Ecosystem (LME) is an international waterbody that supports substantial populations of fish, invertebrates, marine mammals, and seabirds. Among the world's 64 LMEs, the

Yellow Sea LME has been one of the most significantly affected by human development. Large human populations live in the basins that drain into the Yellow Sea. This includes the seaside cities with tens of millions of inhabitants from Qingdao, Tianjin, Dalian, Shanghai, Seoul/Inchon, and Pyongyang-Nampo. People in these urban areas are dependent on the Yellow Sea as a source of food, economic development, recreation, and tourism. Yet, the Yellow Sea is under serious threat from industrial and agricultural waste, extensive economic development in the coastal zone, the unsustainable exploitation of natural resources, and unsustainable fishery practices. This has resulted in the loss of biomass, biodiversity, and habitat.

Governments and the international community have recognized the global importance of the Yellow Sea Ecoregion. Starting in 1992, the Chinese and South Korean governments together developed a trans-boundary approach to the management of the Yellow Sea area with the assistance of UNDP, UNEP, the World Bank, and NOAA. In 2005, a UNDP/GEF project, the Yellow Sea Large Marine Ecosystem project, was officially launched with participation of the Chinese and South Korean governments. Each of the neighboring countries has established a number of MPA most of the adjacent to or in proximity to their coast. In 2002, WWF and other conservation NGOs and research institutes in China, South Korea and Japan began an assessment of Yellow Sea Ecoregion's biodiversity. The objective of this regional partnership was to prioritize conservation actions based on scientific data. In 2005, the Yellow Sea Ecoregion Planning Programme (a joint initiative between WWF, KORDI and the Korea Environment Institute) and the UNDP/GEF Yellow Sea Large Marine Ecosystem Project signed a memorandum of understanding (MoU). The MoU aims to promote one regionally coordinated biodiversity strategy and action plan amongst both projects and the sharing of biodiversity assessments and analysis data.

2.3 China's MPAs in Yellow Sea: conservation priorities and governance

No institutional inventory of the MPA established in China that contained names, location and management status was identified for MPAs in China to date for the purpose of this study. MPA Atlas and MPA Global have record of only a handful of MPAs in China. However, according to various publications such as Yunzhou L. and Fluharty D. (2017) as of the end of 2015, about 250 MPAs had been established in China and 16 new MPAs were designated in 2016. The term MPA, in the Chinese context refers to two categories of marine re- serves: Marine Nature Reserves (MNRs) and Special Marine Protected Areas (SMPAs). The key distinction between MNRs and SMPAs is the level of protection; MNRs are designed to provide full protection and prohibit extractive activities within the protected areas, while SMPAs are protected areas managed with a sustainable use of natural re- sources, allowing multiple uses. Both MNRs and SMPAs can be designated at a national, provincial, municipal or county level depending on the value of the protected targets (Yunzhou L. 2017)

No-take MNRs currently account for 94.4% of the total area of China's MPA system, which differs strongly from the global situation, where no-take zones constitute only a tiny fraction of the global MPA system (Qiu et. al 2009). The designation of national MNRs follows the same procedure as other types of national nature reserves, and national MSPAs are approved and declared by the State Oceanic Administrative instead of the State Council. Local (provincial, municipal and county level) MPAs (including MNRs and MSPAs) are selected, evaluated and designated by local governments. Up to 2016, there were

34 NMRs established in the Yellow Sea covering 19,011 km^2 in addition to MSPA. The first MSPA was approved in 2004, up to 2016 there are 67 MSPA covering 6656 km^2 (Zhang Z., FIO, SOA 2017). Several government ministries and agencies under State Council depending on location and resources managed manage MPAs in China. Among them, the State Oceanic Administration (SOA) oversees the majority of the MPAs and is also responsible for the drafting of various regulations and polices related to the management of the marine environment in China. The first MPA was established and approved by State Council in 1986.

Table 1.3.1 China's Marine National and Local Nature Reserves in Yellow Sea Ecoregion (WWF, KORDI and KEI, 2006)

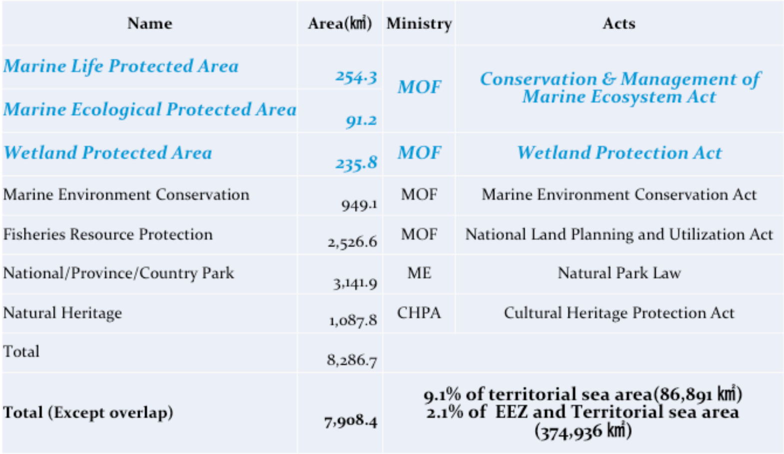
Marine national nature reserves (NNRs)	Location	Areas(hm2)	Important conservation targets	Management authority
Snake Island-Laotieshan Mountain NNR	Lushun, Liaoning Province (Prov.)	17 000	Vipers and birds and their habitats	SEPA
Yalu River Costal Wetland NNR	Donggang, Liaoning Prov.	112 180	Tidelands, wetlands, water birds and migrating birds	SEPA
Changli Golden Seaboard NNR	Changli, Hebei Prov.	30 000	landscape and marine ecosystem	SOA
Chongming Dongtan NNR	Chongming County, Shanghai	4 900	Estuary wetland	SFA
Yancheng Birds NNR	Yancheng, Jiangsu Prov.	453 000	Hooded Cranes and tidelands, wetlands	SEPA
Nanji Islands NNR	Pingyang County, Zhejiang Prov.	20 106	Islands, molluscs and marine ecosystem	SOA
Tianjin ancient seaboards and wetlands NNR	Tianjin	21 180	Ancient seaboards relics of conch dykes and oyster beaches, wetlands ecosystem	SOA
Huanghe River Delta	Dongying, Shandong Prov.	153 000	Original wetland ecosystem and water birds	SFA
Shuangtai Estuary water birds NNR	Panjin, Liaoning Prov.	80 000	Hooded cranes, Siberian cranes, Swan goose, etc.	SFA
Marine local nature reserves (LNRs)	**Location**	**Areas(hm2)**	**Conservation Targets**	**ManagementAuthority**
Dalian Haiwang nine-islands marine NR	Dalian, Liaoning Prov.	2 143	Seashore physiognomy, seaboard scenes and seabirds	Liaoning Provincial Gov.
Dalian Laopian Island NR	Dalian, Liaoning Prov.	1 580	Marine creatures and ecosystem, Karst and marine abrasion physiognomy landscape	Liaoning Provincial Gov.
Sanshan Island NR	Dalian, Liaoning Prov.	200	Chlamys (Azumapecten) farrer, Haliotis discus hannai, and other rare seafood	MOA
Jinshitan Geology NR	Dalian, Liaoning Prov.	2 200	Particular geological structures, paleontologic fossils and particular seaboard physiognomy	SEPA
Zhujiatun marine abrasion NR	Dalian, Liaoning Prov.	1 350	Marine abrasion physiognomy	SEPA
Liaodong Bay wetland-marine NR	Panjin, Liaoning Prov.	80 000	Water birds, Largha seals and other rare marine creatures	Liaoning Provincial Gov.
Rare marine creatures NNR	Changhai County, Liaoning Prov.	220	Breeding area for Chlamys (Azumapecten) farrer, Haliotis discus hannai and 黄刺参(Stichopus japonicus??) and habitat for prawns migration.	SEPA
Suizhong arenaceous seaboard and biodiversity NR	Suizhong County, Liaoning Prov.	20 7700	arenaceous seaboard and marine ecosystem	SOA
Huanghua Chenier NR	Huanghua, Hebei Prov.	117	Chenier and plants within the area	SOA
Leting Shijiutuo Island NR	Leting County, Hebei Prov.	3 775	Animals exp. Birds and plants	Hebei Provincial Gov.
Miaodao Islands marine NR	Changdao County, Shangdong Prov.	875 600	Birds and warm temperate zone island ecosystem	SOA
Qingdao Dagongdao Island ecosystem NR	Qingdao, Shandong Prov.	1 600	Birds, marine creatures and their habitats	Shandong Provincial Gov.
Qianliyan Island ecosystem NR	Yantai, Shangdong Prov.	1 823	ever-green broad-leaved forests and birds	Shandong Provincial Gov.
Wuli shells dykes and wetland NR	Wuli County, Shangdong Prov.	80 480	Chenier seaboard—wetland	Shandong Provincial Gov.
Rongcheng Chengshantou Marine NR	Rongcheng, Shangdong Prov.	3 000	Seaboard physiognomy and lagoon ecosystem	SOA
Rongcheng Sanggouwan NR	Rongcheng, Shandong Prov.	13 333	Rare marine creatures	SEPA
Jimo Marine creatures NR	Jimo, Shandong Prov.	915	Economic marine products	SEPA
Jinshan three-islands marine NR	Jinshan County, Shanghai	4 000	Marine ecosystem, sub-tropic zone plants	SOA
Wuzhishan birds islands NR	Zhoushan Islands, Zhejiang Prov.	470	Seabirds	Zhejiang Provincial Gov.
Ningpo marine relics NR	Ningpo, Zhejiang Prov.	456	Ancient sea embankment relics	SOA

2.4 Overview of South Korea's MPAs in Yellow Sea, conservation priorities and governance

There are seven MPA categories in South Korea established by domestic laws and regulations and applied to national parks, natural monuments, and conservation of marine resources. There are also a range of regulations applied to MPAs under different authorizing ministries and agencies such as the Ministry of Ocean and Fisheries, Korea Fisheries Resource Agency, and Cultural Heritage Protection Administration.

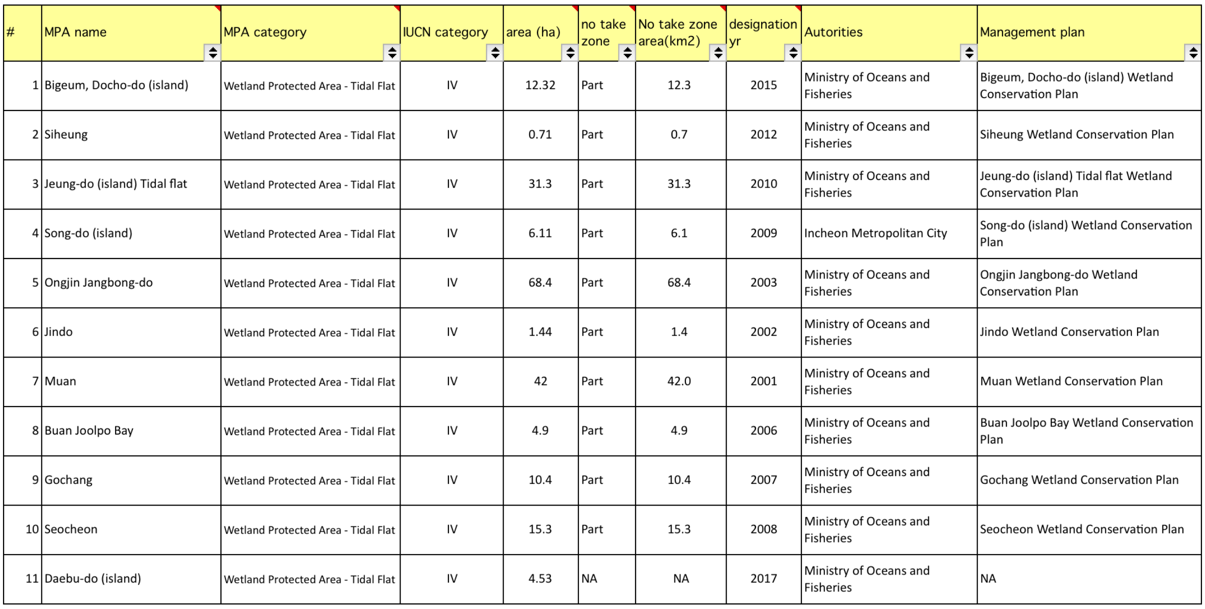
One unique characteristic of MPAs in Korea is that wetland protection has been made a priroity, and a number of wetlands on the west coast, within the Yellow Sea, have been protected. Small islands scattered around the Korean waters are under protection of the Specific Islands category. Korea also has an MPA category for fishery resources protection and its sustainable use. Areas belonging to this category account for 30% of the total MPAs in Korea but do not fall under the categories of IUCN. The total number of MPAs in Korea that comply with the CBD target is 27 and the area is 7,908.4 km^2, accounting for 9.1% of the Korean territorial sea and 2.1% of the EEZ and territorial sea area as shown in Table 1.3.1. Eleven of the twenty seven MPAs are located in the Yellow Sea Eco-region as shown in table 1.3.2

Table 1.3.2 Coastal and Marine Protected Areas of Republic of Korea (as of Dec. 2017) as designated by 6 district laws and managed by 3 ministries.



Name	Area(㎢)	Ministry	Acts
Marine Life Protected Area	*254.3*	*MOF*	*Conservation & Management of Marine Ecosystem Act*
Marine Ecological Protected Area	*91.2*		
Wetland Protected Area	*235.8*	*MOF*	*Wetland Protection Act*
Marine Environment Conservation	949.1	MOF	Marine Environment Conservation Act
Fisheries Resource Protection	2,526.6	MOF	National Land Planning and Utilization Act
National/Province/Country Park	3,141.9	ME	Natural Park Law
Natural Heritage	1,087.8	CHPA	Cultural Heritage Protection Act
Total	8,286.7		
Total (Except overlap)	7,908.4	**9.1% of territorial sea area(86,891 ㎢) 2.1% of EEZ and Territorial sea area (374,936 ㎢)**	

Table 1.3.3 MPA in Republic of Korea along the Yellow Sea (personal communication with KOEM staff, December 2017)



#	MPA name	MPA category	IUCN category	area (ha)	no take zone	No take zone area(km2)	designation yr	Autorities	Management plan
1	Bigeum, Docho-do (island)	Wetland Protected Area - Tidal Flat	IV	12.32	Part	12.3	2015	Ministry of Oceans and Fisheries	Bigeum, Docho-do (island) Wetland Conservation Plan
2	Siheung	Wetland Protected Area - Tidal Flat	IV	0.71	Part	0.7	2012	Ministry of Oceans and Fisheries	Siheung Wetland Conservation Plan
3	Jeung-do (island) Tidal flat	Wetland Protected Area - Tidal Flat	IV	31.3	Part	31.3	2010	Ministry of Oceans and Fisheries	Jeung-do (island) Tidal flat Wetland Conservation Plan
4	Song-do (island)	Wetland Protected Area - Tidal Flat	IV	6.11	Part	6.1	2009	Incheon Metropolitan City	Song-do (island) Wetland Conservation Plan
5	Ongjin Jangbong-do	Wetland Protected Area - Tidal Flat	IV	68.4	Part	68.4	2003	Ministry of Oceans and Fisheries	Ongjin Jangbong-do Wetland Conservation Plan
6	Jindo	Wetland Protected Area - Tidal Flat	IV	1.44	Part	1.4	2002	Ministry of Oceans and Fisheries	Jindo Wetland Conservation Plan
7	Muan	Wetland Protected Area - Tidal Flat	IV	42	Part	42.0	2001	Ministry of Oceans and Fisheries	Muan Wetland Conservation Plan
8	Buan Joolpo Bay	Wetland Protected Area - Tidal Flat	IV	4.9	Part	4.9	2006	Ministry of Oceans and Fisheries	Buan Joolpo Bay Wetland Conservation Plan
9	Gochang	Wetland Protected Area - Tidal Flat	IV	10.4	Part	10.4	2007	Ministry of Oceans and Fisheries	Gochang Wetland Conservation Plan
10	Seocheon	Wetland Protected Area - Tidal Flat	IV	15.3	Part	15.3	2008	Ministry of Oceans and Fisheries	Seocheon Wetland Conservation Plan
11	Daebu-do (island)	Wetland Protected Area - Tidal Flat	IV	4.53	NA	NA	2017	Ministry of Oceans and Fisheries	NA

3. SCALING UP TO MPA NETWORKS

3.1 Benefits of MPA networks

Effective MPA networks can magnify the benefits of individual sites, protect large-scale processes, slow the loss of endangered marine species and restore depleted fisheries (IUCN 2008). There are several **international commitments** to the development of MPA networks:

- The 5th World Parks Congress meeting in 2003, the 2002 World Summit on Sustainable Development, the United Nations Convention on Biological Diversity (CBD) 2004 Program of Work on Protected Areas, and CBD 2007 all called upon the international community to establish, by 2010 or 2012 (depending on which commitment), a global system of effectively managed, representative networks of marine and coastal protected areas.
- In 2016, the IUCN's "Protected Planet Report" called on the importance of protected areas (PAs) for sustainable development due to economic and social values for existing and future generations (Aichi Biodiversity Target 1). It called to make MPAs a part of national and local responses to address biodiversity loss, improve food and water security, increase resilience of human communities to cope with natural disasters and to promote human health and well-being (Aichi Biodiversity Target 14).
- The AICHI Biodiversity target 11 aimed, by 2020, to protect at least 10% of the coastal and marine areas, especially those of importance for biodiversity and ecosystem services, through ecologically representative, well-connected systems of protected areas, integrated into wider seascapes.
- Lastly, at 86 years old, famed biologist E.O. Wilson wrote a book for biodiversity conservation titled "Half Earth: Our Planet's Fight for Life." At the IUCN World Conservation Congress, while not an official IUCN declaration, Wilson shared his message that we needed to conserve 50% of the world's areas as permanent preserves, undisturbed by humans to protect biodiversity of the planet as a permanent preserve.

These calls and commitments stem from the evidence that MPA networks are necessary to improve the health of our oceans. Individual MPAs are not sufficient in either scale or effectiveness to achieve sustainable ocean management. A well designed and operational MPA network is a system of individual marine protected areas defined by connectivity and operating cooperatively, at various spatial scales, with a range of protection levels that fulfill biodiversity goals and conservation and management objectives more effectively, efficiently and comprehensively than individual sites could alone. Social, economic and fisheries benefits should be realized over time from the scaling up of individual sites to networks of MPAs, providing the potential for sustainable oceans and development opportunities.

A broad range of stressors impact our marine ecosystems and threaten the linkages and connectivity between habitats and species. Networks of MPAs can help restore these ecosystems and allow habitats, species and biophysical processes to stay connected. Networks provide more protection than individual MPAs because, if designed properly, they allow for replication, representativeness, connectivity and resiliency, among other things. Because most marine organisms use more than one habitat during their lives, by encompassing multiple habitats, MPA networks can protect species throughout their life history.

Wrasse from the sea-grass bed to the market in Bais, Negros (Quiros, 2012 & 2014)

For a network to be effective, it is essential that it provide long-term arrangements for resource protection, funding, management and enforcement. Similar to the challenges faced by individual MPAs, funding and enforcement are often the weakest links. Enforcement and compliance considerations must be built into network design. Rules must be consistent with—and contribute to—the network's objectives. Primary considerations include feasibility, affordability, public understanding and protecting areas most vulnerable to impact from human activities. Compliance is when people accept and act in accord with the rules and regulations of the MPA network. Building compliance requires that policy-makers, government leaders and citizens are aware of the network's regulations and that they agree that they are needed—bringing these stakeholders in as partners into the design of the MPA network can help meet the enforcement and compliance challenge.

Ecological, economic and cultural benefits can be provided by MPA networks depending on their design goals, such as:

- Ensures that important marine habitats, such as breeding, nursery and feeding grounds are at least partially protected
- Ensures that threatened, vulnerable or overexploited species of a given area will have adequate habitat space, in order to continue reproducing
- Ensures that some of the larvae spillover from one MPA can settle within its dispersal range

- Enhances fisheries production for a given management area because the larval production, dispersal, and fish spillover effects are maximized through planning
- Ensures that migratory and wide-ranging species are protected by continuous corridors of MPAs
- Ensures that upstream/downstream impacts on living and marine resources are managed at the appropriate scale so as not to displace impacts from one MPA to the next (e.g., water quality, introduced species)
- Builds capacity in MPA management across individual MPA management bodies
- Creates a shared information base for MPAs and stakeholders that helps in making management choices
- Provides a logical reason for individual MPAs and stakeholders to coordinate with each other to share experiences
- Provides financial and administrative partnering possibility between MPAs and other institutions and sectors within a network
- Provides maintenance of ecosystem services, such as coastal protection provided by reefs and mangroves, and fisheries productivity
- Provides mitigation and adaptation potential from climate change, by sequestering carbon and providing resiliency through replication
- Enhances productivity, helping to support local industries of fisheries, tourism and related activities
- Provides quality habitats and ecosystems for potentially non-disruptive activities such as kayaking and diving
- Helps maintain, conserve and protect areas of cultural or spiritual significance

Scaling up from single MPAs to MPA networks

MPA networks are not created rapidly, but evolve over time. This concept paper is intended to be used during a technical workshop or training to help progress towards a functional network in the region by convening YSLME MPA Network and others likely to be involved in the network, forming a participatory framework to share ideas, lessons learned and work as teams through a variety of issues. This contact alone provides the start for a social network.

Not just any collection of MPAs can be called a MPA network. A MPA network is a collection of MPAs that interact in some *meaningful* manner to meet management and/or conservation objectives of the network.

The IUCN (2008) suggests five biophysical and ecological principles should guide the design and implementation of MPA networks:

1) include the full range of diversity in the biogeographic region

2) ensure that ecologically significant areas are incorporated

3) maintain long term protection

4) ensure ecological linkages

5) ensure maximum contributions of individual MPAs to the network

An effective MPA network is composed of individual MPAs that each satisfies the requirements of an effective MPA as highlighted herein and has both ecological and social components. **Criteria** that may weigh a decision towards an area with more potential for conservation enhancement and inclusion in a network are:

- **habitat quality:** areas with generally superior habitat quality or better than the average for the general area (e.g., coral cover, seagrass, water quality, etc);
- **uniqueness, rarity:** habitats that are populated by unique flora and fauna, such as seamounts or wetland areas;
- **special importance for life history stages:** areas that contain breeding, spawning or foraging grounds, are migratory corridors or are important to threatened species;
- **oceanography:** areas with favorable currents that tend to aggregate larvae and organisms inside the MPA but with periodic flushing to the outside;
- **biodiversity:** areas with higher than average biodiversity and a range of functional groups and of animals on the food chain;
- **productivity:** areas, such as estuaries, upwelling zones, transition zones, and continental margins, that are known for high biological productivity;
- **vulnerability:** areas that are known to be vulnerable, sensitive or slow to recover due to slow growth or low reproductive rates, such as deep water corals and sponges;
- **size:** areas that cover a significant range of the habitat that is important to the life history of the priority species to be protected (ideally based on the needs of the species with the greatest area needs);
- **spacing:** areas in close enough proximity for larval dispersal and/or for areas to be used during different life stages;
- **shape:** areas that capture biogeographic features, transition zones, or depth gradients, but also allow for clear markings of boundaries (e.g., easily delineated);
- **replication:** redundancy in habitats across the network for resiliency and replenishment (e.g., if one seagrass bed declines in health or is damaged by storm surge or an oil spill, another may not be). Replication also allows for larval dispersal between sites and improves the statistical analytical power when evaluating change;
- **connectivity:** to ensure habitats used during different life history stages are protected, as well as linkages between larval production areas;
- **resiliency:** areas that have demonstrated resilience (resilient systems are adaptable, flexible);
- **resistance:** areas that have demonstrated resistance to disturbance;

- **social acceptance:** areas that will not create unnecessary social conflicts;
- **special importance:** areas that have cultural or historical significance;
- **practicality of management:** areas where zones can be effectively established and enforced given the resources that will be available for protection, as well as zones where networks can maintain equity by addressing the needs of different user groups;
- **quality of management:** areas where management programs and regulatory frameworks can be effectively implemented and sustained over time.

Tourists visiting Malcatop Island, Palawan and Puerto Galera, Mindoro (Quiros, 2012)

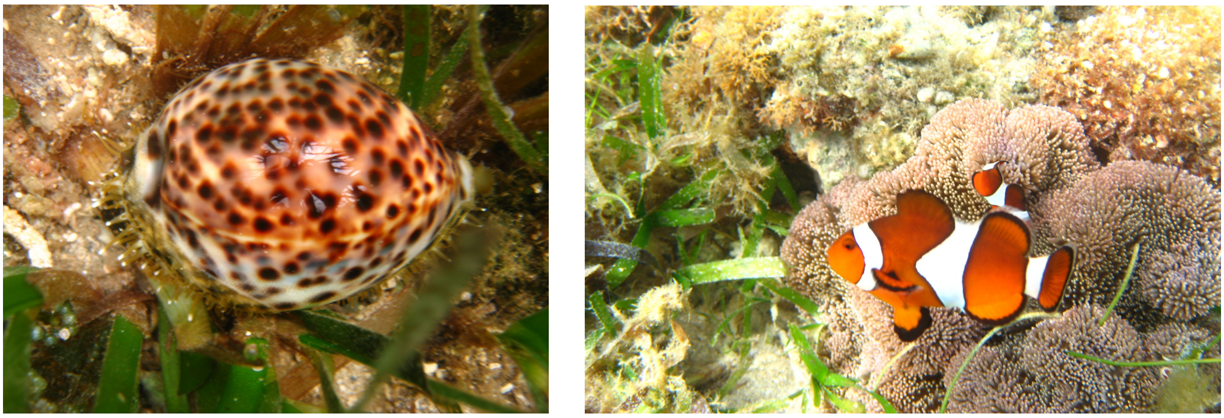
As with individual MPAs, MPA network design is dependent on the goals of the network. To be successful, the network, regardless of type, must have clearly stated and defined goals or objectives. This will likely require an evaluation of the management and conservation objectives for all of the individual MPAs that may be part of the network to determine goals in common. Network goals or objectives are often on a different scale than those of individual MPAs; however, they should be complementary, reflecting the needs and objectives of the individual sites within the network. A network can only fulfill its potential when it is designed to achieve a goal and is part of a broader framework that encompasses other aspects of coastal management in an integrated fashion. Network goals should also take into account the concept of shifting baselines. Rather than accepting existing status, refer to historical status with the goal to restore marine ecosystems and associated populations to previous productivity and biodiversity levels.

Setting clear and agreed-upon network goals or objectives at the outset is important for many reasons:

- guide designation of component sites, levels of protection and management needs
- guide monitoring and adaptive management of network sites
- guide opportunities to reduce, mitigate or eliminate activities that degrade resources or ecosystem services, while promoting those that support natural processes
- help determine future investments in sustainable use of coastal and marine resources
- improve transparent decision-making

- provide a framework for reviewing the contribution of existing MPAs to a network
- promote stakeholder buy-in and support (IUCN 2008)

Scaling up from individual MPAs to a network can also benefit from a financial analysis. Financing at the network level will have some efficiencies but also some trade-offs. For instance, deciding whether to pool resources in a network where some MPAs are able to secure more funds from tourism than others, while others might protect a remote site of special significance but do not allow tourism.



Cowrie shell and clown fish (Quiros, 2011)

Additional guidelines for establishing networks:

1. Ensure that MPA network management bodies have community level involvement, such as an advisory board, that helps the management body develop and implement the network management plan together with the local MPA authority.
2. Build on what already exists and evaluate existing MPAs for connectivity with one another and their ability to meet management and conservation objectives.
3. Compile and synthesize the existing data - both ecological and socioeconomic to determine where gaps exist.
4. Develop an effective decision support system, such as data, maps and tools to use (e.g., spatial mapping using Geographic Information System, design planning and evaluation using MARXAN, or other database structure and portal, etc.).
5. Prioritize resource management issues for the network.
6. With the added stress of climate change, consider methods to enhance resiliency, such as protection of functional groups; dynamic MPA boundaries to account for predicted changes in species ranges and oceanographic regime changes; scenario planning for awareness of potential changes; etc.
7. Evaluate cross-cutting management strategies applicable to all the MPAs in the network and across sectors.
8. Support new MPAs. Each MPA that will ultimately be part of an effective network will likely require some level of assistance in some portion of its planning and implementation process to become an active network participant.

9. Develop a plan for sharing of data, resources (e.g., staff, boats, equipment), and contributions (finances).
10. Outline and use an open, transparent and inclusive process to enhance awareness, encourage public participation and support.
11. Incorporate socioeconomic considerations into network design and implementation.
12. Ensure that along with the stated objectives comes the level of protection to achieve the objective (e.g., policy and implementation of enforcement).
13. Work within or integrate with existing integrated coastal management (ICM) plans and regimes.
14. Adopt an evaluation program to determine management effectiveness, including systematic monitoring of indicators and reporting on the effectiveness of the network, which requires the collection of long-term, consistent data, in order to measure changes over time and provide reliable feedback on management effectiveness.
15. Practice adaptive management.

Strategic interventions by government, NGOs, donors, etc., can be used to push the process of network development along. These might include:

- Providing support for MPA monitoring and evaluation that addresses biophysical and management needs using existing protocols.
- Summarizing all relevant data in a geographical (maps) and graphic manner for feedback to communities, and for use in planning and education through simple reports and visual means to keep the data useful at the local level.
- Training and involving local stakeholders in performing the tasks of planning, implementing, monitoring and evaluating an MPA.
- Conducting targeted research studies on the effectiveness of MPAs, the location of new MPAs, social acceptability of MPAs, the oceanography of the area and the location of priority species as deemed relevant for planning and education.
- Mentoring targeted MPA management bodies in a systematic but strategic manner to ensure that management is progressing to a higher level per an MPA rating system
- Sponsoring workshops and informal meetings among MPA managers, management bodies and key stakeholders to help motivate and stimulate social networks.
- Linking existing and future MPA work (data, results, MPA establishment, etc.) with national programs to support MPAs.
- Supporting incentive programs.

These strategic interventions can be sought by the network itself through partnerships and/or grants or initiated by concerned parties outside the network.

As indicated previously, an MPA network is also a network of people managing the component MPAs, benefiting from the network and promoting the networks' viability and longevity. To this end, MPA network planning must be done in connection with the local governments and communities of concern, and in coordination with other projects and stakeholders operating in the area. In summary, the basic attributes of an MPA network include MPAs that are effective in their own right, protect important habitats, contribute to fisheries enhancement, and enhance biodiversity conservation, but also have linkages with and connectivity to other sites within the network. MPA network management bodies must involve a diversity of stakeholders, including community members, and be linked to larger planning areas. And of critical importance to network effectiveness is long-term funding and consistent and fair enforcement of rules and regulations.

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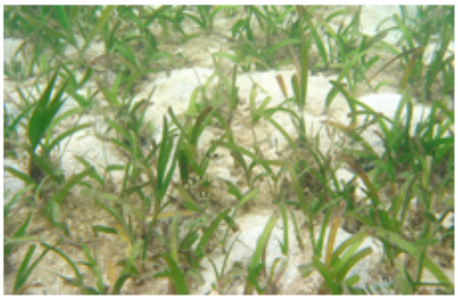
Examples of Habitat Linkages and Function

From Silvestri S, and Kershaw F (eds). 2010. Framing the Flow: Innovative Approaches to Understand, Protect and Value Ecosystem Services Across Linked Habitats. UNEP World Conservation Monitoring Centre, Cambridge, UK. (adapted)

Mangroves: Ecosystem function and connectivity

Bridging the land-sea interface, mangroves are a critical intertidal habitat. As fresh water, nutrients and sediments flow from inland sources, mangroves bind sediment, absorb inorganic nutrients and physically slow freshwater discharge (Valiela *et al.*, 2001). They also provide critical buffering of the shoreline from erosion by storms (Barbier *et al.*, 2008), which can dramatically protect both inland infrastructure and coastal populations in low- elevation areas (Das & Vincent, 2009). Several studies have also found that mangroves can affect the presence and biomass of coral reef fish and other coastal tropical fisheries because they provide important nursery and refuge habitat for juvenile and adult fish (Nagelkerken *et al.*, 2002; Mumby *et al.*, 2004; Aburto-Oropeza *et al.*, 2008).

(Quiros, 2011)



(Quiros, 2011)

(Longo, 2016)

Seagrasses: Ecosystem function and connectivity

Seagrass beds are an essential ecosystem. Seagrass beds grow extensively throughout both temperate and tropical regions, primarily occupying subtidal areas, but sometimes extending into the intertidal (Williams & Heck, 2001). Like mangroves, seagrasses stabilize sediments (Orth *et al.*, 2006), sequester carbon (Duarte *et al.*, 2005), and play a key role in nutrient cycling (Williams & Heck, 2001). As one of the most productive ecosystems in the world (Waycott *et al.*, 2009), they export a substantial amount of particulate organic matter as well as plant and animal biomass, supporting or subsidizing coastal and benthic food webs (Heck *et al.*, 2008). Like mangroves, seagrasses are also an important nursery and foraging habitat for several taxa including invertebrates, fish, birds, and mammals during one or more of their life stages (Williams & Heck, 2001). Many of these species, like dugongs, manatees and several species of sea turtles, are highly threatened by lack of habitat, overfishing or reduced water quality (Hughes *et al.*, 2009). In addition, seagrass extent also affects the diversity and biomass of several species of coral reef fish (Nagelkerken *et al.*, 2002; Dorenbosch *et al.*, 2005; Verweij *et al.*, 2008; Hughes *et al.*, 2009).

Coral reefs: Ecosystem function and connectivity

Coral reefs provide essential services and ecological linkages through seagrasses and mangroves back to terrestrial habitats. Coral reefs exist in a tight ecological relationship with seagrasses and mangroves, serving as the adult or foraging habitat for countless reef fish and invertebrates. Larvae from these populations are often exported back to seagrasses or mangroves for some stage of their lifetime and may migrate between all three habitats. These fisheries are both biologically and economically important.

Sustainable coral reef fisheries generate US$2.4 billion per year in revenue for Southeast Asia alone (Burke *et al.*, 2002). In addition, coral reefs provide the first physical structure for shoreline protection and erosion, slowing the impact of wave action from storms. By reducing storm impacts, coral reefs may not only protect seagrass and mangroves, but also human populations and infrastructure on the coast (Kunkel *et al.*, 2006; Barbier *et al.*, 2008).

3.2 Scientific concepts

Biophysical concepts for designing resilient MPA networks in a changing climate

Climate change, from both natural and anthropogenic factors, affects marine systems on multiple levels of organization, from individuals and populations, to communities and ecosystems (Table 1.2).

Climate change can destroy both ecosystems and livelihoods. Current threats include increases in sea temperature, rising ocean acidity, changing rainfall patterns, and increases in exposure to climate-related hazards such as tropical cyclones, sea level rise, and floods. Specifically, coastal and oceanic fish are affected by water temperature. Climate change alters water temperature and the depth of the surface mixed layer and currents. These changes could expand distributions of water fish to the poles and cause latitudinal shifts in species distributions or contracting species distributions.

Table 1.2. Climate change responses at different scales

Individuals	life history stages, body size, reproduction, diseases, physical responses
Populations	population dynamics
Communities	community composition, geographic distributions
Ecosystems	structure and function, biogeochemical cycling, productivity, trophic-level interactions

Ecosystems are complex networks of abiotic and biotic components, with capacities to adapt to perturbations like climate change. **Resistance** is the property of communities or populations to remain unchanged when disturbed. **Resilience** is an attribute of a system that relates to its potential to resist change from or to recover from disturbance. Both resistance and resilience are attributes of ecological stability, or persistence through time.

While there are uncertainties about the rates and spatial structure of climate change, we need to consider potential changes in ecosystem management planning. For example, individuals can respond to perturbations directly through physical responses to abiotic factors or indirectly through changes in interactions like predation and competition.
Examples of changes in abiotic factors include temperature, salinity and nutrient (food) availability. When many individuals are affected, the individual's response is then translated directly to changes in populations, communities, and then ecosystems (Table 1.3).

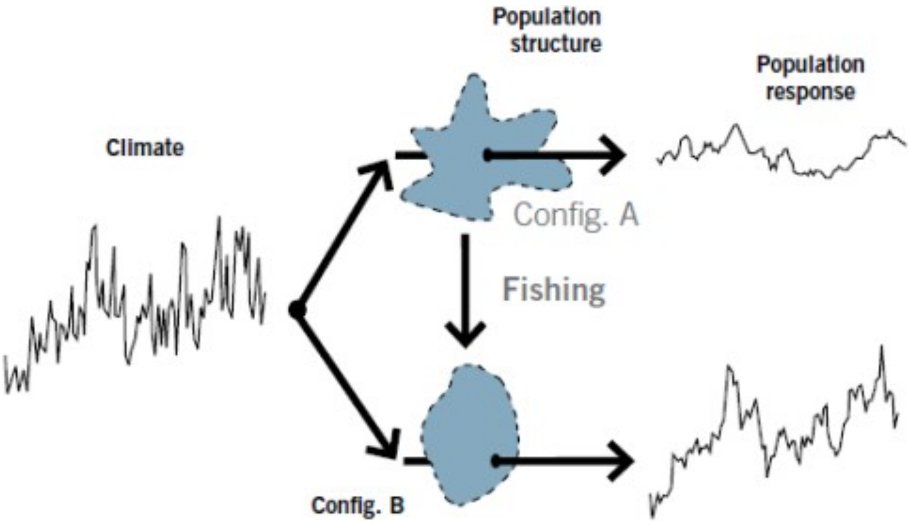
Table 1.3. Properties that affect the resilience of marine systems to climate change

Populations	**Habitats**	**Ecosystems**
Connectivity	Heterogeneity	Connectivity (spatial fluxes, trophic connections, mobile link species)
Dependence on critical habitats	Spatial arrangement and composition	Abundance and size structure of upper trophic levels
Sensitivity to environmental conditions	Foundation species	Community size structure of plankton
Flexibility in migration routes	Ecosystem engineers	Phenological matches
Population size and age structure	Level of disturbance	Species' richness
Geographic distribution	Bathymetry, topography and rugosity	Functional redundancy (taxonomic diversity)
Number of population Sub-units or metapopulations	Habitats supporting critical life stages	Response diversity
Phenology	Biogeographic transition zones	Community evenness
		Beta diversity

Adapted from Brock, Kenchington and Martinez-Arroyo, 2012

It is important to understand the influence climate change has on the different components of connectivity. For example, when a marine system has added stressors like fishing in addition to climate change, we find more complexities, indirect effects and uncertainties in a population's response. There is increased vulnerability in marine populations (abundance) when climate change effects are combined with fisheries exploitation (Fig. 1.4). Climate change could also change connectivity patterns by changing larval duration times, adult movement and species distribution.

Figure 1.4.



From Perry et al, 2010; Brock, Kenchington and Martinez-Arroyo, 2012

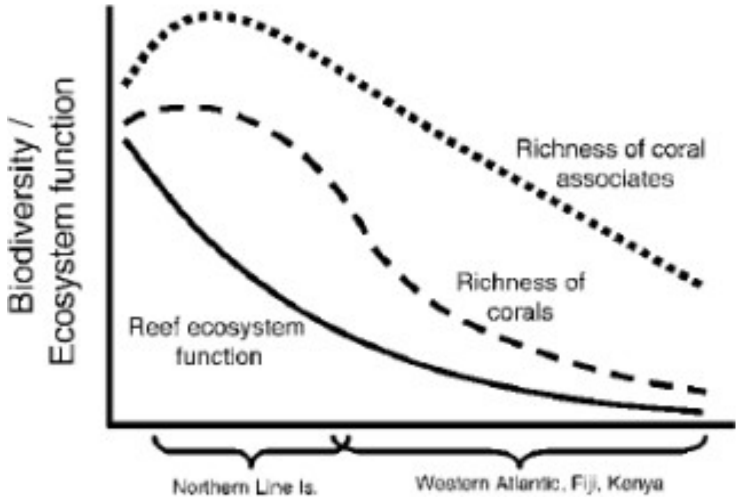
A **shifting baseline** is a type of change to how a system is measured, usually against previous reference points (**baselines**). These reference points may be significantly different from even earlier versions. The problem of shifting baselines is evident in coral reef systems. Coral reefs lack baselines of pristine conditions because they are so heavily degraded. Scientists do not have a clear understanding of how coral reefs functioned before major human impacts. They have little understanding of certain attributes of coral reefs such as trophic structure, biodiversity, resistance and resilience before human impacts, so comparing current reefs to ones with little human influence is a helpful exercise because comparing current to future reef conditions could be basing comparisons on an already-degraded system.

Fig. 1.5: Illustration of a healthy versus collapsed coral reef

To look for differences between healthy or collapse systems, coral reef studies have looked at reefs inside and outside MPAs (Fig. 1.5). The problem is that published studies of differences in biodiversity in coral reefs have been done on coral reefs that are already affected by humans. Even the most pristine reefs are still impacted by human disturbance.

The **Intermediate Disturbance Hypothesis** (IDH) predicts that diversity should increase at low levels of human disturbance because competitively dominant species are suppressed. Diversity decreases as disturbance increases to severe levels, which are harmful for more species. The IDH would look like a bell-shaped curve. However, when only disturbed reefs are studied, we see decreases in diversity with increasing disturbance, and not the classic bell-shaped curve (Fig. 1.6).

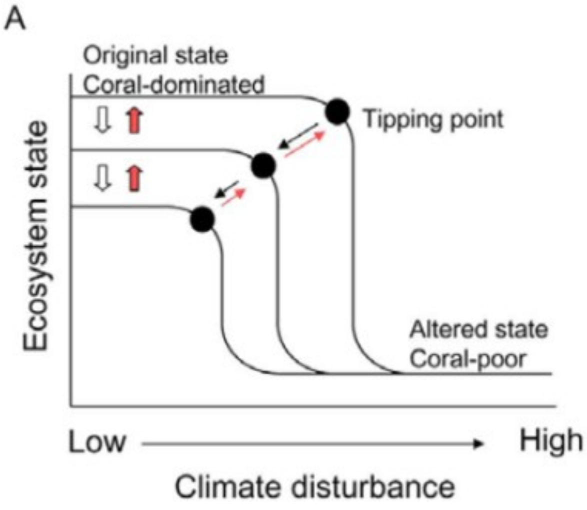
Fig. 1.6. Biodiversity decreases with increasing local human disturbance



From Knowlton and Jackson, 2008

One schematic of resilience shows that natural communities are highly resistant to climate change with low to medium levels of disturbance, they do not change their ecosystem state (Fig. 1.7). In coral reefs, the original state would be a coral-dominated reef. The **tipping point** (black circle) is a level of disturbance that leads to an alternative ecosystem state, which is far to the right of the graph, or a coral-poor reef. With chronic anthropogenic disturbance degrading the ecosystem (white arrows), the tipping point in response to climate change shifts to the left (black arrows), making the system less resilient to disturbance. Management interventions (red arrows) should aim to control local anthropogenic disturbances to reverse the degradation (block red arrows), shifting the tipping point back to the right, to higher resilience (red arrows).

Fig. 1.7. Resilience in coral reef ecosystems



From Cote and Darling, 2010

MPA network designers should think about the previous anthropogenic stressors (such as overfishing, which alters ecosystem food webs, or land-based runoff, which brings sediment that smothers corals and seagrasses, degrading the biogenic, or living habitat), when considering objectives related to current states of ecosystems. Some climate change impacts affecting species and habitats, such as changes to ocean temperatures, can be mitigated through MPA networks when MPAs have adequate representation of a variety of habitats that span different oceanographic conditions.

Given these climate change stressors and the potential for natural systems to adapt and for humans to mitigate the effects of climate change, MPA networks must be designed to provide a mechanism to adapt to and mitigate climate change effects on ecosystems.
MPA networks can contribute to ecosystem resilience by addressing connectivity (connecting critical places for life stages of key species), habitat heterogeneity, spatial arrangement and composition of habitats. MPA networks can reduce other pressures, such as fishing, and support abundance and size structure of upper trophic levels and species richness through the MPA size and placement.

MPA networks can be designed to adapt to and mitigate climate change with these **four guidelines**:

1. Protect species of "conservation concern" and habitats with crucial ecosystem roles
2. Protect potential carbon sinks
3. Protect ecological linkages and connectivity pathways
4. Protect the full range of biodiversity in the targeted biogeographic area

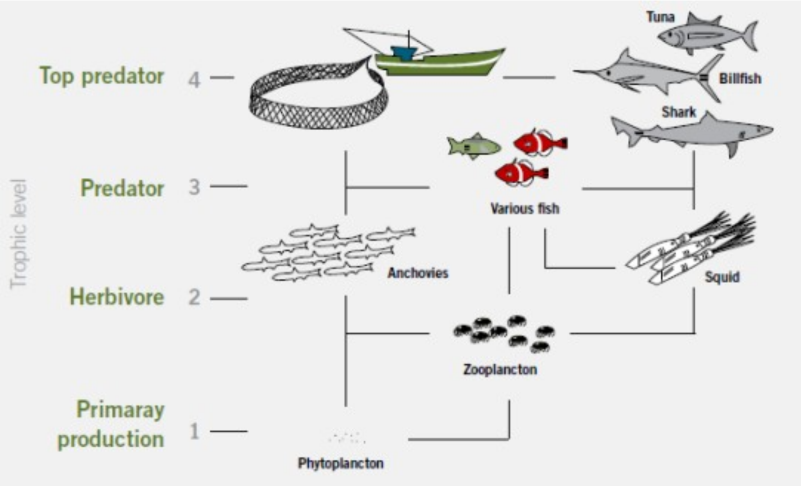
MPA networks are currently designed for contemporary environmental and habitat conditions. MPA managers and planners will need to see if the current MPA networks will meet their objectives under future climate change scenarios and uncertainties.

Top predators

Top predators are species of "conservation concern" because they drive or structure ecosystems and ecosystem processes. Their presence impacts many others in the ecosystem and if their population decreases, it can have important ramifications on the ecosystem. If a predator is removed, population densities of other species in the community change. Top predators like sharks and tunas can have a "top down" impact on the ecosystem by consuming large amounts of prey (Fig. 1.8). Top predators change the size, abundance and distribution of lower trophic species. In the following graphic, phytoplankton are at the base of the food chain, followed by zooplankton, which are preyed upon by anchovies, or forage fish, and other fish species. Squid eat zooplankton and are also prey to top predators. Top predators are also prized by recreational and commercial fishermen.

Food web condition helps determine the resilience of ecosystems. Top predators can have a top-down impact called a **trophic cascade**, which is an alternating pattern of increased and decreased abundance at successive lower trophic levels. There is reduced resilience of heavily fished Mexican coral reefs due to the effect of hurricanes.

Figure 1.8.



From Perry et al, 2010; Brock, Kenchington and Martinez-Arroyo, 2012

Planktonic species (like copepods) are food for a range of upper trophic level species that have commercial and ecological importance. These are food for larval and juvenile forage fish (like sardines) that are prey for marine birds, marine mammals, other fish and top predators. Plankton species are very sensitive to changes in water temperatures, salinity and dissolved oxygen levels. Increasing water temperatures result in smaller sized phytoplankton and zooplankton, affecting growth of forage fish.

Carbon sinks

MPA networks can help mitigate effects of climate change by preserving species, ecosystems and habitats that are important for carbon sequestration. Carbon sinks or carbon sequestration are any process, activity or mechanism that removes a greenhouse gas or an aerosol from the atmosphere. Blue carbon sinks occur in the ocean, where living organisms capture carbon in sediments from mangroves, salt marshes and seagrasses. While these habitats can store carbon, they need to retain the carbon trapped in the system. If they do not, they can be sources of carbon to the atmosphere, with the release of trapped carbon as carbon dioxide and methane.

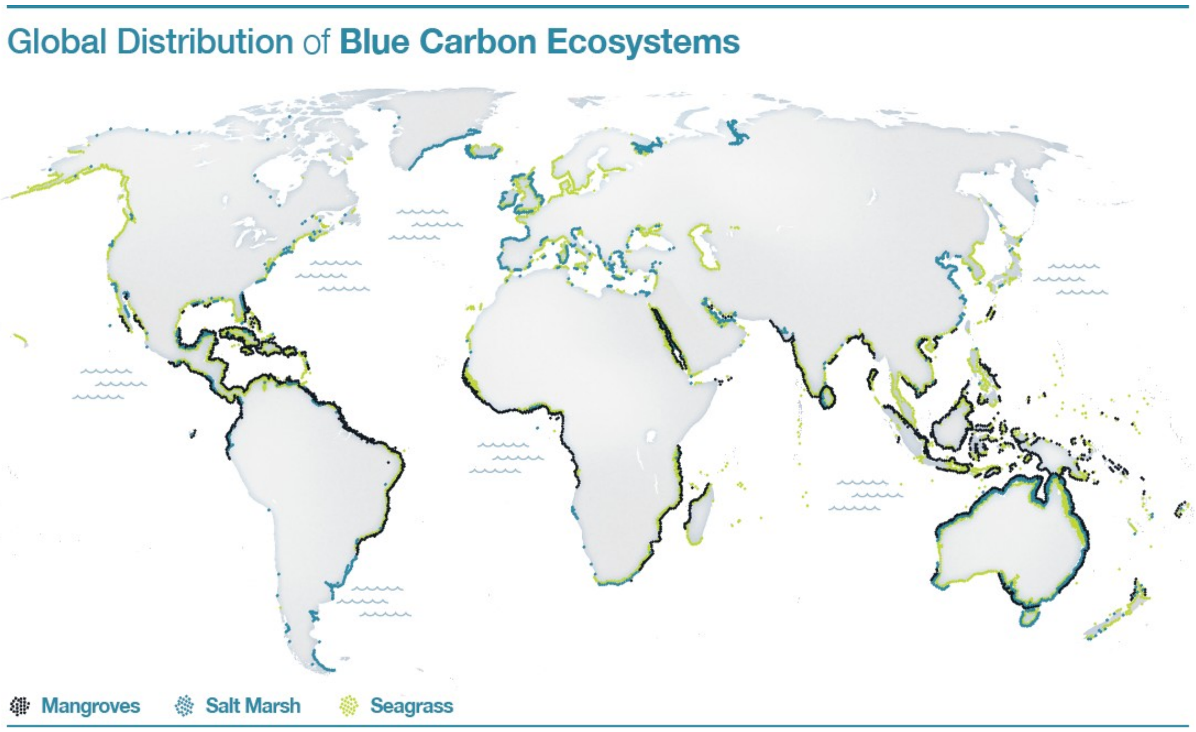


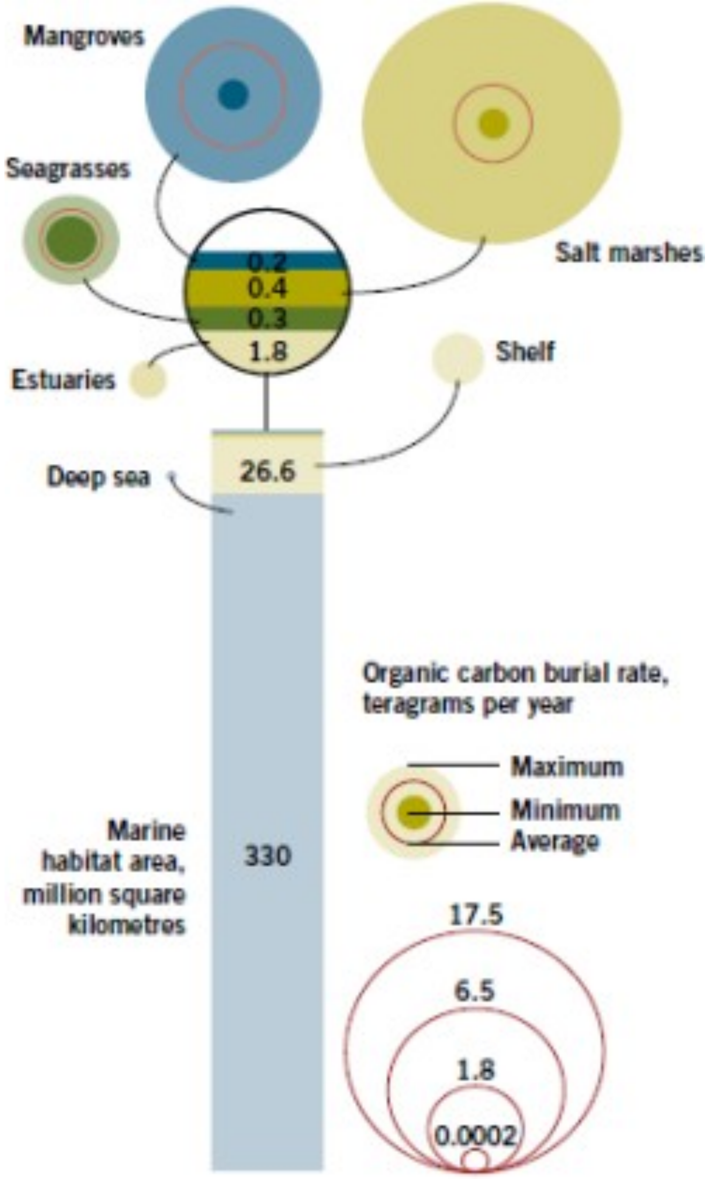
Figure 4. Global distribution of the blue carbon ecosystems

From http://thebluecarboninitiative.org/blue-carbon/

Mangroves, salt marshes and seagrasses are the sources of blue carbon. These habitats are on the coast or in estuarine systems, so they are influenced by stressors like land- based impacts and coastal development. **Up to 980,000 hectares of this important habitat is destroyed each year**. There has been a 30% decrease in seagrass area, or a loss of over 100 km2 per year since 1980. At this rate, 30-40% of tidal marshes and seagrasses and nearly all unprotected mangroves may be lost in the next 100 years (Green A, White A, Kilarski S. 2013).

Salt marshes are the greatest source of coastal blue carbon, followed by mangroves, and then seagrasses.

Fig. 1.9. Blue carbon sinks



From Nellemann, et al., 2009; Perry et al, 2010; Brock, Kenchington and Martinez-Arroyo, 2012

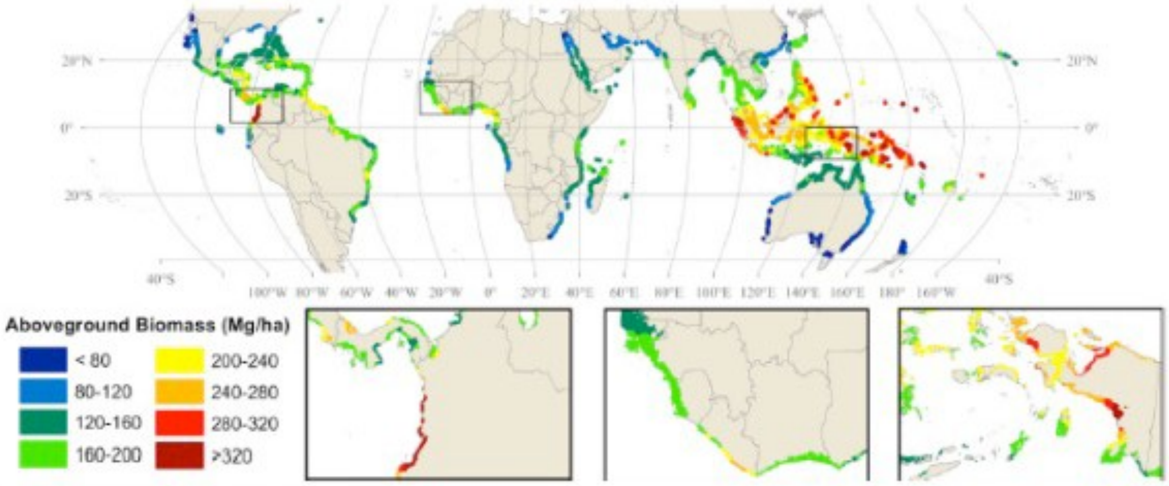
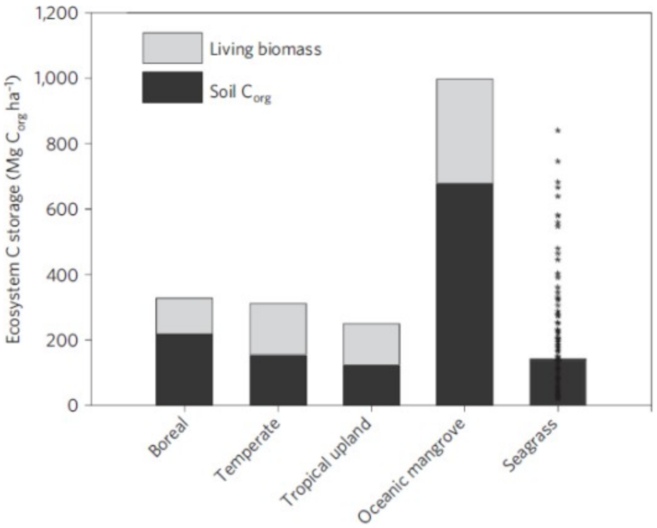
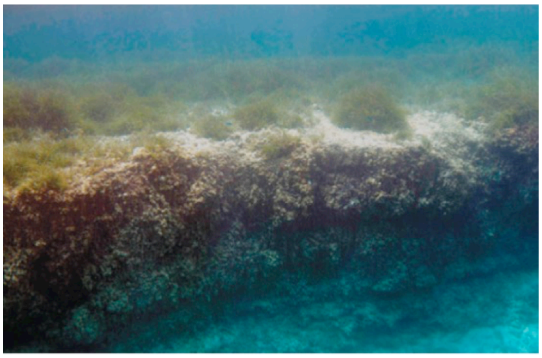


Figure 2 Global mangrove map showing modelled patterns of above-ground biomass per unit area.

Global map of mangrove above-ground biomass (Hutchison et al, 2013)

Hutchison et al modelled above-ground biomass (AGB) of mangrove coverage around the world using field data and created this map showing patterns of above-ground biomass of mangroves per hectare. This map shows a concentration of mangrove biomass in the coral triangle. The total AGB was 2.83 Pg, with an average of 184.8 tons of carbon in AGB per hectare.





Posidonia oceanica 'mattes' that can be as thick as 2.7 meters in shallow waters of the Mediterranean

Organic carbon storage is mostly belowground in the sediment (Fourqurean et al, 2012)

Fourqurean et al modelled organic carbon stocks in seagrass meadows using published and unpublished studies of seagrass above ground and below ground carbon stocks across the globe. They estimate that globally, the below-ground stocks can reach 19,9 Pg organic carbon, but the seagrass carbon pools average between 4.2 and 8.4 Pg carbon. Mediterranean seagrass meadows have the largest organic carbon stores because of their deep "mattes" of sediment and below ground material.

Adjacent ecosystems

The coastal ecotone is an intersection of terrestrial and near shore marine ecosystems that cover a wide array of spatial scales; high in organismal diversity and density, it is a site for cross-ecosystem exchange of materials such as organic matter, nutrients, and sediment. Increased human populations will likely exacerbate the degradation of coastal habitats, creating an acute need for effective solutions to mitigate human impacts.

MPAs have the potential to protect ecosystems, and even enhance or restore productivity of coastal and marine fisheries. MPAs cannot work alone, however they should be used with other management tools such as integrated coastal management (ICM) and fisheries management. Benefits from MPAs are related to management outside the MPAs (such as terrestrial protected areas, and coastal and watershed management adjacent to the MPA), and ocean uses outside the MPA (such as shipping, industry and energy uses). On the local level, threats to theYellow Seamarine environment include impacts on water quality from watersheds, coastal development and tourism.

MPA networks are limited in protecting against terrestrial impacts such as land-based development and pollution. Fluxes between marine and terrestrial systems have largely been ignored when establishing both terrestrial and marine reserves, and there has been little work identifying the ecological, social, and economic links between these adjacent ecosystems. Consequently, there is increasing interest in integrated coastal management principles that attempt to incorporate connectivity between terrestrial and marine systems.

Seagrasses are used to assess the health of the nearshore marine environment with studies showing that siltation from suspended inorganic solids and upstream watersheds, sediment burial, water pollution and sediment deposition all impact seagrass condition.
Seagrass species population declines are due both directly or indirectly to anthropogenic impacts, and there is a call to reduce watershed nutrient and sediment inputs to seagrasses to stem seagrass loss.

References of particular relevance to biophysical concepts include these and the references cited therein.

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SUPPLMENTARY READING: p. 9-31: Scientific Guidelines designing resilient MPA networks in a changing climate

4. BIOPHYSICAL MPA NETWORKS

4.1 Overview of biophysical MPA networks

A network implies a coordinated system of MPAs linked through biological and administrative levels, reflecting consistency in finance, management and monitoring. An MPA network is also a network of people managing the components of individual MPAs and promoting the network's viability and longevity, sharing experiences to enhance each other's efforts in management. Networks take various forms. There are ***social networks*** formed by communication and sharing of results and coordination of administration and planning[1]. There are ***ecological networks*** formed by ensuring that natural connections between and within sites enhance ecological functions and benefit one or more MPAs. And there are ***management-based networks*** formed by creating consistency and efficiency in areas such as enforcement, monitoring and awareness building. All three types of networks, social, ecological and management-based, need to be integrated and coordinated to maximize their potential benefits. But to form effective social, ecological and/or management-based networks of MPAs, we must consider factors that will ensure the networks created will add value to existing conservation efforts.

The success of MPAs and MPA networks is dependent on many factors. Several best practices have been identified by IUCN (2008) and others as being key to success, including the following:

- Clear goals and objectives
- Long term political support and support of institutions, legislation and legal authority
- Participation of communities in decision-making
- Involvement of people with diverse interests
- Effective use of scientific information and advice, but also use of best available information and the precautionary approach, such that networks are established and later adjusted as additional information becomes available
- Effective conflict-resolution mechanisms
- Sustainable finance
- An integrated management framework with other coastal management efforts
- Equitable sharing of economic benefits
- Active and fair enforcement
- Adaptive management

Keep in mind these factors and how they might be addressed in developing a framework for your MPA network.

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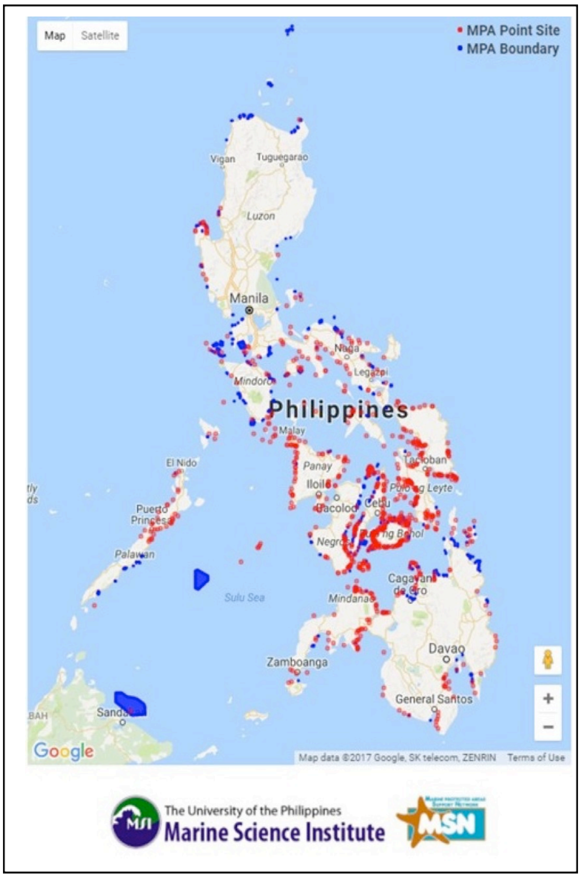
[1] Note: we are making a distinction herein between social networks of MPA practitioners and partners, which we cover in this concept paper, and social connectivity of user groups of ecosystem services in the network or region

Case Study

Building the National Marine Protected Areas Support Network to sustain effective management in the Philippines

(http://mpasupportnetwork.org)



Project Summary

The MPA Support Network (MSN) supports over 500 MPAs in the Philippines:

1) Establishing a national institutional mechanism for engaging local initiatives and national partnerships in **sustaining adaptive management**;
2) **Mainstreaming a complementary monitoring and evaluation system** integrated with incentives through performance-based schemes such as the Outstanding MPA of the Year (OMY) recognition awards;
3) **Documenting good practices** through the continuation of Reefs through Time series and proceedings of the National MPA Congress together with a donors workshop that will prioritize, complement and document national and local efforts in the context of global initiatives. The MPA Support Network will promote among its partners to contribute to national MPA databases.

Project Objectives

The overall goal of this effort is to ensure that MPAs promote integrated coastal and marine management, in order to contribute to the sustainable development of Philippine coastal resources for the sustenance of local communities. Specifically, the objectives are:

1) Formulate the National MSN and develop an action plan in line with the vision and objectives of the Philippine Marine Sanctuary Strategy

2) Facilitate exchange of information, best practices and concerns regarding effective MPA establishment and management

3) Encourage comparable (if not common) monitoring and evaluation methods for effective MPA management

4) Create and advocate incentive systems and campaigns that recognize reef stewardship and successful MPA establishment and management

5) Develop communication and education programs or materials that will motivate people to take conservation action

6) Facilitate sourcing and leveraging of funding support for sustainability of MPA management and deployment and coordination of national plans of action

4.2 Biological or Ecological MPA Networks

A biological or ecological MPA network is a collection of MPAs carefully chosen to maintain functional marine ecosystems over space and time. They can be established to achieve various goals but generally speaking are established for (1) biodiversity conservation or (2) biodiversity conservation and fisheries enhancement.

Key aspects for biological or ecological networks to be successful include:

- The need for some area within each MPA to be fully restricted from fishing or other resource extraction activities to allow for there to be a source for replenishment of other areas. The 5th World Parks Congress called for MPA networks to fully protect (e.g., exclude extraction of resources) in 20 to 30 percent of each habitat type;
- Knowledge of habitats in the MPAs (and region), ideally with acoustic mapping and the development of habitat maps;
- Knowledge of at least key species that use the MPA (or region) and their habitat use during different life stages (ontongeny) or behaviors (e.g., foraging, migrating, resting), and;
- Connectivity to exist between areas. Thus, studies to evaluate connectivity are necessary.

Critical areas to consider include:

- Feeding grounds, breeding and spawning grounds, nursery grounds, areas of high species diversity, socializing areas, migratory routes, and etc.
- Vulnerable marine habitats (e.g., rocky reefs, coral reefs, seagrass beds, mangroves, etc.), which provide critical ecosystem processes.
- Source populations (if they can be identified). These are desirable in MPAs.
- Refuges understanding the different needs of a target species in different life stages, as well as the risk of mortality in each stage, can help to determine which areas best act as refuges for these species and should be selected as MPA sites.
- Replication of representative habitats to diminish the risk of impacts affecting all.
- Areas that provide ecosystem services to people.

A key premise of an ecological network is that the MPAs interact through ecological and/or oceanographic linkages. These connections may include:

- Connections between habitats such as coral reefs and seagrass beds, not only as species corridors but for habitat protection and nutrients;
- Connections through regular larval dispersal and settlement between and within the MPA sites;
- Movements of mature marine life in their home range from one site to another dependent on habitats or because of regular or random spillover effects from MPAs; and
- Connectivity between and among habitats to provide migratory corridors.

Many habitats are reliant on one another (see text box in Section 1.1), and many animals rely on more than one habitat through the course of their life cycle, and even through the course of a day. Animals often spawn in one habitat, inhabit another habitat while they are young, and as adults live in yet another habitat. Examples of animals that use multiple habitats include many crab, snapper and rockfish species, sea turtles, and marine mammals.

Networks can be driven by fisheries benefits resulting from spillover, larval recruitment and protection of reproductive potential. Monitoring of the biophysical, social and economic outcomes of MPA networking becomes the reason for demonstrating incentives for good stewardship, and at the same time, buy-in promotes public-private partnerships. Recognition awards for contributions to MPA networks is an option that can be used to stimulate network level collaboration.

Biophysical design principles for designing resilient MPA networks in a changing climate

To achieve fisheries sustainability, biodiversity conservation and ecosystem resilience in the face of climate change in the Yellow Sea, there are **15 principles** that are highly relevant for field practitioners in the design, planning and implementation of MPA networks. These principles should be used in conjunction with important social, economic and political considerations in marine spatial planning:

1. Prohibit destructive activities throughout the management area.
2. Represent 20-40% of each habitat within marine reserves (depending on fishing pressure and if there is additional effective protection in place outside of reserves). Include habitats that are connected through movements of key species
3. Replicate protection of habitats within marine reserves.
4. Ensure marine reserves include critical habitats (e.g. spawning, feeding and nursery areas).
5. Ensure marine reserves are in place for the long-term (20-40 years), preferably permanently.
6. Create a multiple use marine protected area that is as large as possible.
7. Apply minimum and variable sizes to MPAs (depending on key species and how far they move, and if other effective marine resource management methods are in place).
8. Separate marine reserves by 1 to 20 km (with a mode between 1 and 10 km).
9. Include an additional 15% of key habitats in shorter-term marine reserves.
10. Locate MPA boundaries both within habitats and at habitat edges.
11. Have MPAs in more square or circular shapes.
12. Minimize and avoid local threats.
13. Include resilient sites (refugia) in marine reserves.
14. Include special or unique sites in marine reserves (e.g. habitats that are isolated or important for rare and threatened species).
15. Locate more protection upstream.

Refer to Green et al. 2013 for more details.

The following table summarizes various MPA networks around the world. See website links for details.

MPA Network name	**Location**	**Reference**
Northern Shelf Bioregion of British Columbia	British Columbia, Canada	http://mpanetwork.ca/bcnorthernshelf/
MPA Collaborative Network	California, USA	http://www.mpacollaborative.org/aboutus.html
North-East Atlantic OSPAR network	Western European countries	https://www.ospar.org/work-areas/bdc/marine-protected-areas
Marine Mammal Protected Areas Network (MAMPAN) and the Sister Sanctuary Program	Bermuda, Caribbean Netherlands, Dominican Republic, French Antilles, USA	http://www.caribtails.org/conservation.html
United Kingdom MPA Network	United Kingdom and across the European Union	http://jncc.defra.gov.uk/default.aspx?page=4549

5. ROLE OF BIOPHYSICAL CONNECTIVITY IN MPA NETWORK DESIGN

5.1 Biophysical Connectivity Principles

Ecological connectivity is the exchange of individuals among geographically separated populations, when marine ecosystems maintain connections with adjacent and distant ecosystems through the movement of juvenile and adults across ecosystem boundaries. However, there is variation in juvenile versus adult connectivity, and spacing between individual MPAs may be optimal for one species but not for another. For example, if an MPA is too big, the larvae settle and the juveniles remain inside, reducing potential spillover to other areas. For sedentary species, a large number of small MPAs may be optimal to maximize larval export. For highly mobile species, it may be better to have a few large MPAs, which increase the likelihood that the adults stay inside the MPA. A "stepping stone" approach can also be used to protect key habitats of highly migratory species.

MPAs in a network should connect and interact through ecological and oceanograhic linkages natural connections between and within individual sites that enhance the ecological function of and benefits to each site. A network can help ensure ecosystem function by encompassing temporal and spatial scales at which ecological systems operate. Ecological linkages include:

- Connectivity between disparate habitat types (e.g., coral reefs and seagrass beds)
- Regular larval dispersal in water columns between and within MPAs
- Regular settlement of larvae from one MPA into another MPA
- Movements of adult marine life in their home range from one site to another, dependent on habitats, or because of regular or random spillover effects from MPAs
- Movement of marine life from one habitat to another during different life stages and for different activities (e.g., foraging versus resting habitat)

Network planners must understand and apply all available information on biological, chemical and physical linkages within the network and beyond. Just as MPA network design must account for connectivity within and between networks, network design must also factor in the impacts of activities outside network boundaries, including terrestrial linkages to coastal watershed catchments (IUCN 2008). There are numerous models that have been developed to evaluate connectivity. Regional or site-specific information should be used to populate the models and/or local studies conducted to accurately reflect local conditions.

Historically, there has been an assumption that marine populations were replenished by distant populations, with the implication that localized management efforts were not critical. However, we now know that many organisms are more localized in their dispersal ability. Consequently, local management efforts are critical for long-term sustainability of these populations. Of course, this depends on the marine species and its use of the seascape or "neighborhood". For instance, large migratory species can have ranges of several thousand kilometers; pelagic fish such as blue fin tuna range over 100 to several thousand kilometers; smaller fish and benthic (bottom dwelling) invertebrates have ranges of only one to several hundred kilometers; and sessile species have ranges of even less than one kilometer. Selecting target species, functional groups and habitats, and understanding their needs throughout their life cycles and for ecosystem health is critical.

Networks are most effective when each type of habitat is represented in more than one MPA, and when individual MPAs are big enough and close enough to protect adults and young. MPA networks can provide insurance because a catastrophe that harms populations and habitats in one marine MPA may not affect other MPAs. The unaffected MPAs can help replenish nearby populations damaged by a catastrophe.

The success of a habitat and its associated organisms is dependent on a variety of factors that can change over space and time. By protecting several replicates of similar habitats in the network the likelihood increases that at least one habitat will be healthy in any particular year. Healthy patches of habitat export plants and animals to the other patches, which can help restore those that have not fared well.

To function as a network, the MPAs must be close enough to connect with each other through movement of animals. Enough of the abundant young fishes and invertebrates that leave one MPA should be able to settle into another to ensure sustainable populations. Consequently, a network may be designed so that individual MPAs are large enough to accommodate the movement of adults, while spacing among MPAs accommodates the longer-distance movement patterns of young.

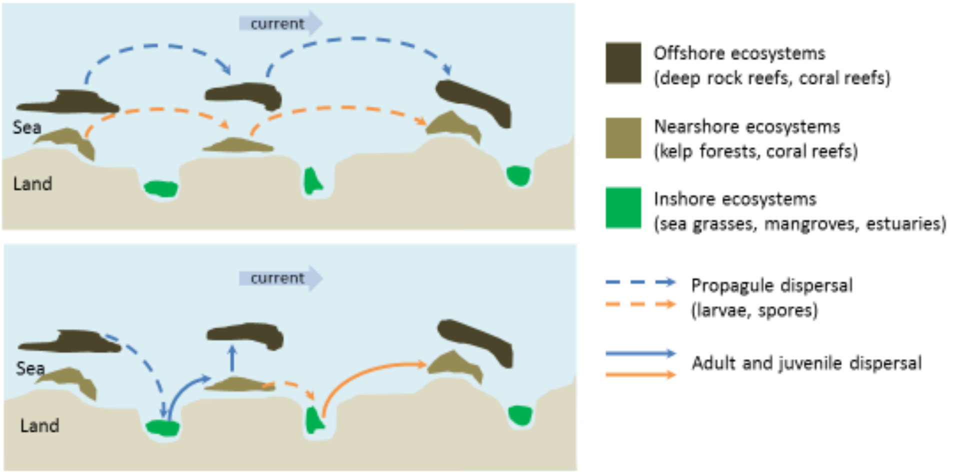
5.2 Connectivity of populations, communities and ecosystems

Ecological spatial connectivity refers to processes by which genes, organisms, populations, species, nutrients and/or energy move among spatially distinct habitats, populations, communities and ecosystems.

Population connectivity results from the movement of individuals of a single species among patchily distributed "local" or "sub-" populations.
Genetic connectivity (also called "gene flow") is the movement of genes among distinct populations of a single species and results from the movement of organisms¾whether spores of marine algae or the larvae, juveniles or adults of marine animals¾among these populations.
Community connectivity results from the movement of multiple different species among distinct ecological communities.
Ecosystem connectivity results from the movement of multiple species among distinct ecological communities, along with the movement of chemicals (e.g., nutrients and pollutants), energy (in the form of organisms), and materials (e.g., sediments and debris). (Carr and Robinson, 2017)

1) Population (demographic) connectivity

The movement of individuals between populations - metapopulations

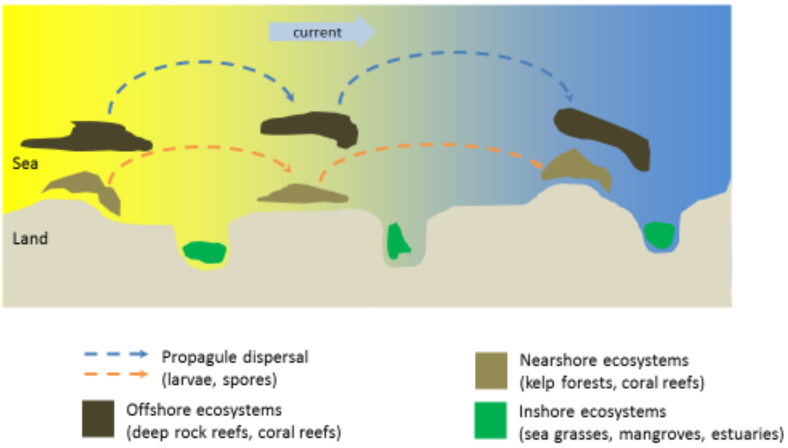


Propagule (larvae, spores) dispersal is fundamental mechanism of connectivity
(contrast with terrestrial and marine mammal populations)

Demographic connectivity is connecting **metapopulations** (a group of populations that are separated by space but consist of the same species) through dispersal of propagules by ocean currents.

2) Genetic connectivity

The movement of genes among populations

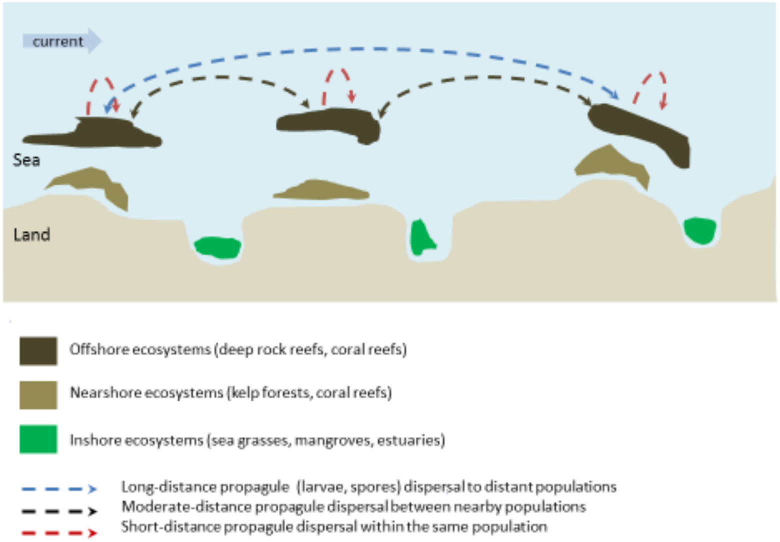


Genetic composition of a species can vary across environmental gradients and barriers to dispersal

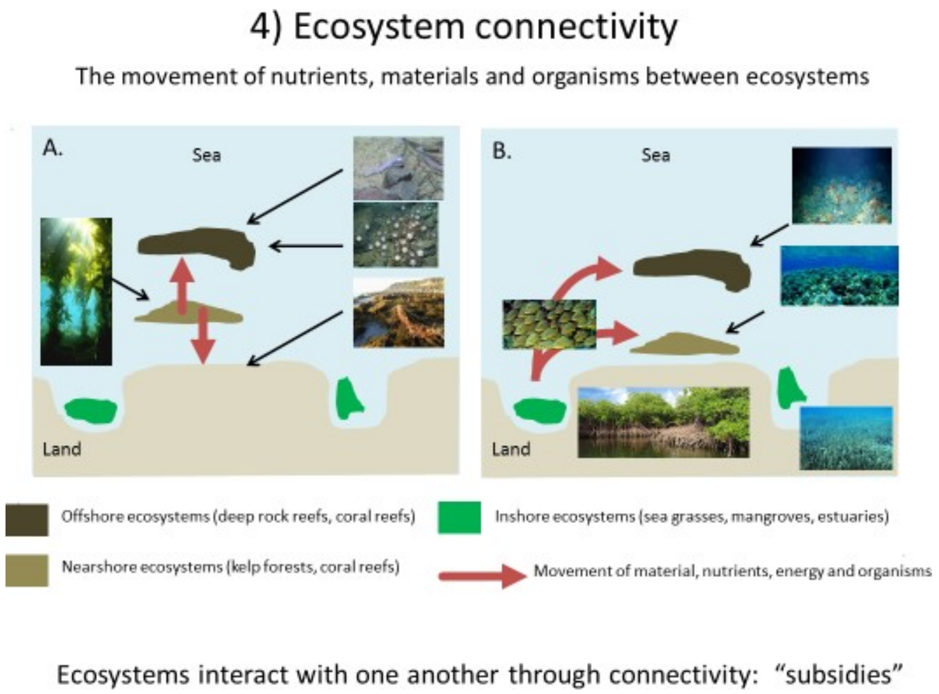
Species ranges extend across a gradient of environmental conditions (water temperature) that lead to variations in the genetic composition of the population across a species/ range. This variation is greater if there are physical barriers to reduce dispersal of larvae across a species range.

3) Community connectivity

Movement of multiple species between communities - metacommunities



Community connectivity is when multiple species move between communities, forming **meta-communities.**


4) Ecosystem connectivity

The movement of nutrients, materials and organisms between ecosystems

■ Offshore ecosystems (deep rock reefs, coral reefs)

🟩 Inshore ecosystems (sea grasses, mangroves, estuaries)

■ Nearshore ecosystems (kelp forests, coral reefs)

➡ Movement of material, nutrients, energy and organisms

Ecosystems interact with one another through connectivity: "subsidies"

Ecosystem connectivity is the movement of nutrients, materials and organisms between ecosystems. This is called a **subsidy**.

5.3 Different forms of connectivity

Population connectivity can be managed by the scale and spacing of MPA networks. **Planktonic larval duration** (PLD) of marine fish and invertebrates is an index of potential connectivity. With increased PLD, there is also a decline in reproductive isolation.

Temperature affects the PLD, with increasing PLD at lower temperatures and higher latitudes because warmer temperatures accelerates larval development. Dispersal distances decrease as temperatures increases. A long PLD increases the potential for long-distance dispersal, so genotypes can mix. PLD is a result of ocean currents, stratification, and temperature that all affect the dispersal and survival of larvae.

Case Study
Reef-fish dispersal validate no take MPAs in the Philippines

(from Abesamis et al, 2017)

Larval dispersal studies among no take marine reserves and fishing grounds in the Philippines were conducted using genetic parentage analysis on a butterfly fish (*Chaetodon vagabundus*). Comprising 90 km of coastline, including Apo Island MPA, 25 inshore fringing reefs, and 23 no take marine reserves, the area is managed by 8 separate municipalities, and linked by a strong current, the Bohol Jet. The no take marine reserves were established at different times since 1982 by fishing communities or municipalities without the intention of forming a network.

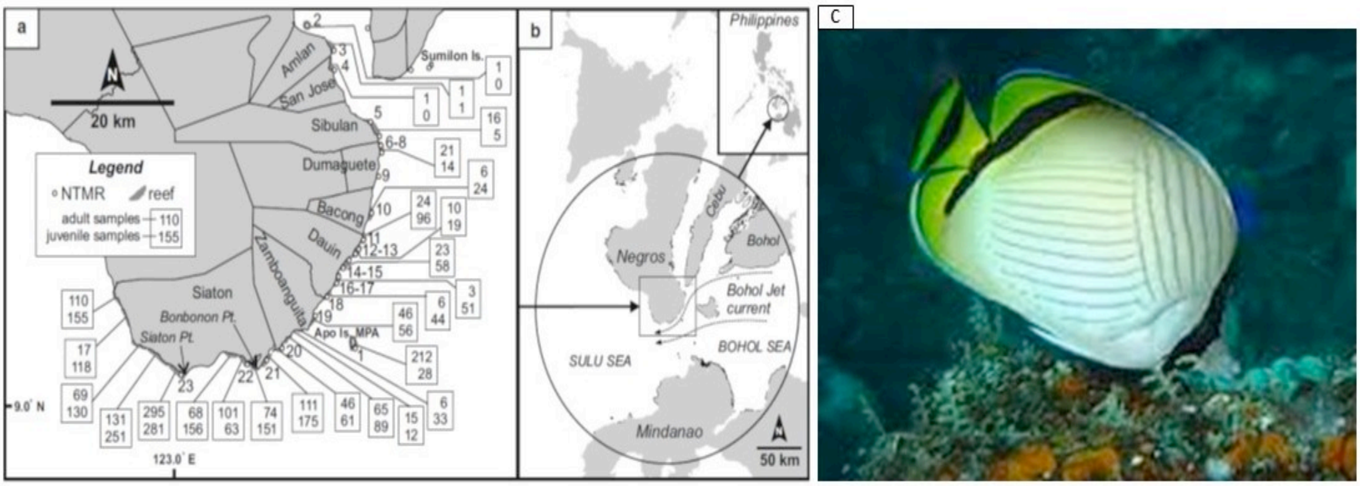


Figure shows map of southern Negros (a), location in the Visayas (b), butterfly fish, *Chaetodon vagabundus* (c)

Abesamis et al. studied the butterfly fish, which has a pelagic larval duration (PLD) of 3-4 weeks. Juveniles recruit in intertidal and shallow reefs before migrating to deeper reefs when they mature. Adults and juvenile butterfly fish from 26 sites were sampled for tissue and DNA, genotyped using microsatellites and analyzed for parent-offspring relationships. Butterfly fish otoliths were also counted to estimate fish age.

Larval dispersal was wind driven, in the direction of the surface currents. Larvae would settle within 33 – 83 km, with indicates a dispersal distance of 36.5 km. These results suggest that creating a network of closely spaced (< 10 km apart) no take marine reserves can enhance recruitment for protected and fished populations in network.

In some situations, fisheries management implemented in one municipality may have greater impact on the fish outside their jurisdiction. Feedback from larval supply could be weaker within a single municipality or a single no-take MPA, compared to collaborative management between two or more adjacent municipalities. This study shows the importance of nested management and cooperation among ecologically connected but politically separated management units, to be able to use the recruitment subsidy effect of individual no-take MPAs.

On a different scale are **mobile link organisms**, which are organisms that actively move across the landscape. Mobile link organisms can contribute to ecosystem resilience because they act as a buffer between sites and can recolonize a location after it is disturbed.

Migration routes can contribute to resilience when they are flexible. Large whales, sea turtles, tunas, swordfish, sharks and seabirds may be able to adapt to varying temperatures during the switch from migration to feeding areas, but they are highly sensitive to temperatures in spawning areas. In addition, changes to the migration routes, resulting in longer migratory paths and a decrease in fitness.

Green sea turtle and humpback whales (Quiros, 2011 & 2016)

Wide-ranging species

Marine mammals, primarily cetaceans, depend on large amounts of these planktonic species and forage fish and are therefore sensitive to their availability. Their greatest threats come from the lack of availability of prey species, vessel traffic and vessel collisions, and fishing gear entanglements.

One challenge of MPAs for cetaceans is that it is difficult to have an MPA around a highly mobile species. Some marine mammals have high site fidelity, though many are highly migratory and cross international boundaries. Cetaceans are highly vulnerable to anthropogenic threats and can be good focal species for their ecosystem because we know a lot about them, compared to other parts of the ecosystem. Cetaceans are too mobile to have the total range inside a single MPA, so a network of MPAs to protect their critical habitat for feeding, breeding and rearing their young is an important endeavor to protect.

Figure 1.10 shows the life stages of cetaceans and how they can migrate between discrete feeding and breeding areas. Protected areas can be placed in these critical habitats. Feeding grounds, in particular, are hotspots which can be managed.

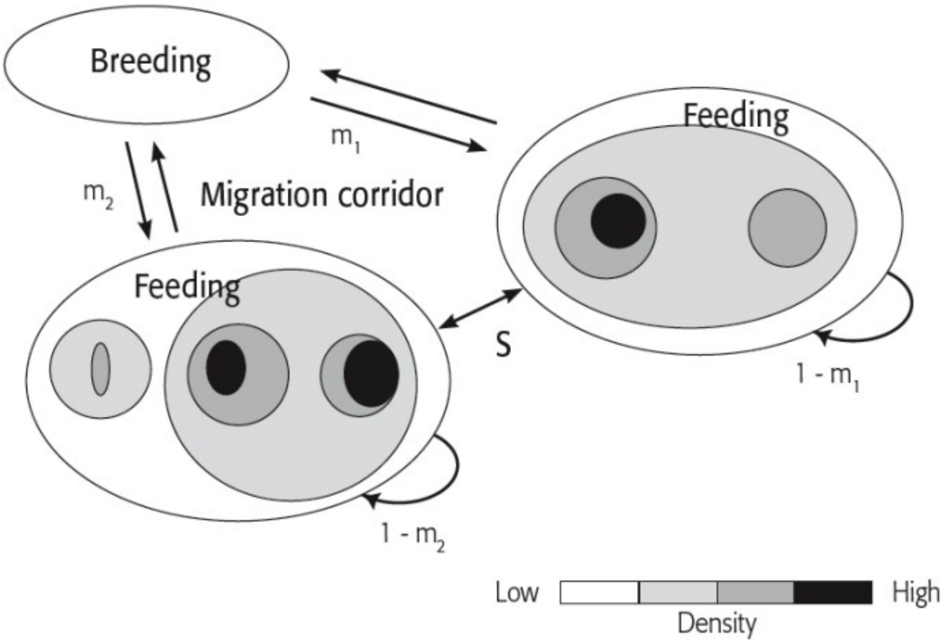


Figure 1.10. Shows life stages of cetaceans, separated into feeding and breeding areas, and the migrations between them.

The first step in establishing MPA networks for cetaceans is to find an area with rich cetacean fauna; these critical areas are used for feeding, breeding, calving, nursing and social behavior. They can encompass migration routes, corridors and resting areas; seasonal concentrations of cetaceans; and areas of importance to cetacean prey, such as those that support productivity or have topographic structures for foraging opportunities.

Certain human activities may create conflict with cetaceans; these include certain fishing activities with cetacean bycatch; intensive whale watching or marine tourism; solid waste pollution that can cause direct entanglement risk and polluted water outflows that may impact health of marine species; and military exercises that sometimes use underwater explosions that can impair and kill marine mammals from the sound. MPAs may be able to prevent potential threats from the expansion of these impacts into the MPA. These threats are direct, indirect and global. **Direct threats** cause mortality such as fishery bycatch, direct takes, ship strikes and military sonar. **Indirect threats** include overexploitation of lower trophic levels (cetacean prey) and habitat degradation (acoustic and chemical pollution, marine debris, disturbance and physical habitat destruction). **Global effects** include climate change. MPAs can directly address fishing net entanglement, ecosystem changes caused by changes in prey resources through fisheries, mortality from direct takes and military sonar. However, MPA networks cannot protect against pollution, marine debris like plastics and climate change.

In the Yellow Sea, the diversity of marine mammals species in the YSLME includes 15 species of whales and dolphins, 4 species of seals and sea lions have been recorded. There is a freshwater population of Finless porpoise (Neophocaena phocaenoides) in Yangtze River, which is the only know freshwater population in the world. Although Eurasian otter (Lutra lutra) is not a strictly marine mammal, estuaries and marine coves in the south-western part of the Korean peninsula is an important habitat for this species (Appendix 1. Key Species and Conservation criteria for YSLME)

5.4 Managing for multiple species

While networks of MPAs provide refuge for populations where over-fishing or disturbance could lead to collapse of populations, connectivity between individual MPAs depends on ocean circulation, the size and spatial arrangement of MPAs, and the life history traits and dispersal ability of species of interest. This optimization is straightforward when considering only a single species. However, with increasing emphasis on ecosystem- based management, sustainable ecosystem services, and climate change adaptation, we look to preserve whole assemblages of species. *How can we design MPA networks for several populations within a community?*

Metapopulations are groups of discrete populations which are separated by space but are of the same species. These populations are either isolated or interact as individuals, moving or migrating from one population to another. Each local habitat in a metapopulation is called a subpopulation. Each subpopulation or local population has a risk of extinction; there is an equilibrium between local extinctions and colonizations of empty suitable habitat patches. However, metapopulations remain stable for a long time, because individuals disperse within the different habitat patches.

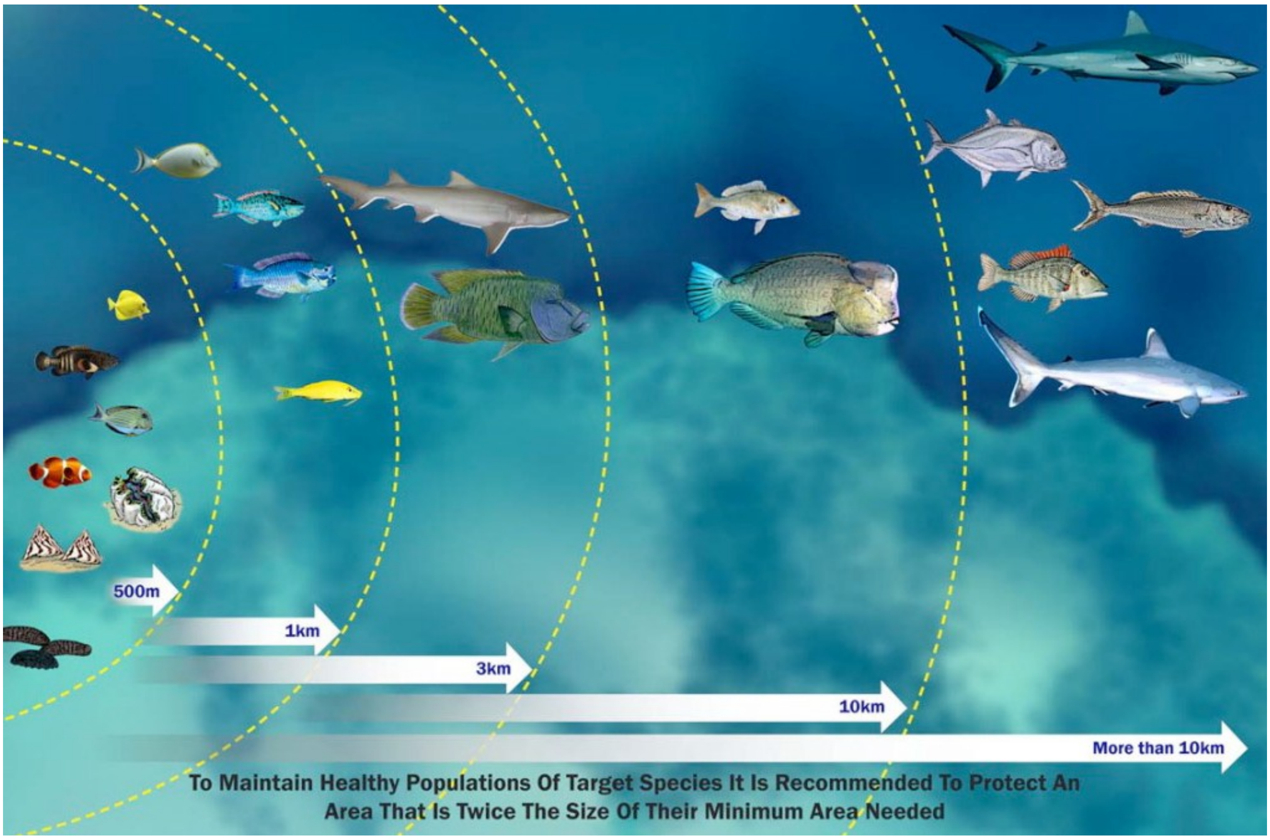


Fig. 1.11. Shows different fish species with different home ranges, of different sizes (Green et al. 2013)

Case Study

How to select networks of marine protected areas for multiple species with different dispersal strategies

(from Jonsson, Jacobi, Moksnes, 2016**)**

Modelling metapopulations of 4 rocky intertidal species with different dispersal strategies, Jonsson, Jacobi and Moksnes (2016) identified a consensus network that used an optimization algorithm which considered the needs of individual species and synergies when MPAs have positive effects on several species at the same time. They incorporated spawning season, PLD, and depth where each larval type maintains its vertical position. Modelling over 8 years, they found optimal MPA networks that maximized the growth rate of the whole metapopulation.

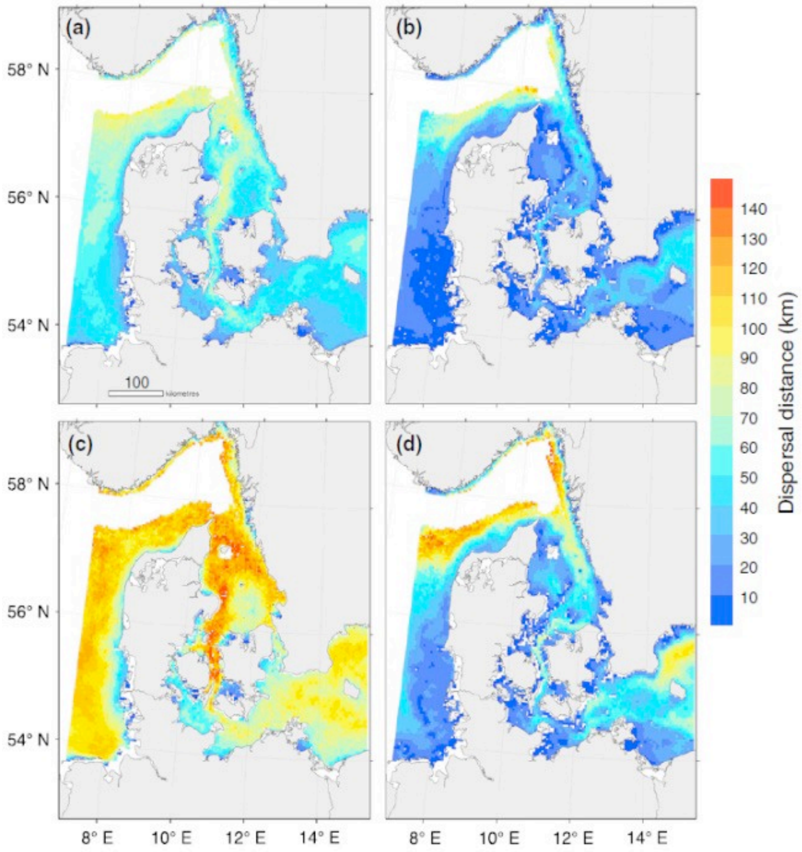


Figure 1 shows mean dispersal distances for four different species in the North Sea: Species A, B, C and D.

Multiple species network selection findings:

(1) Consensus optimal networks resulted in an 80% increase in metapopulation size versus existing MPA networks, which increased metapopulation size by 20%

(2) It is important for all 4 species to co-occur in all MPAs in the network at high densities

(3) Consensus networks depended on the degree of overlap between optimal networks of individual species

(4) Intraspecific variation in larval dispersal traits made it easier to select a consensus network that ensures connectivity of MPA sites for species with multiple dispersal strategies

(5) Successful conservation should maintain the species assemblage within the MPA network, with different dispersal strategies co-occurring

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