

Ecological Connectivity for Marine Protected Areas

The role of ecological connectivity in the effective design and management of marine protected area (MPA) networks is gaining attention in the field of marine conservation. This document provides an introduction to ecological connectivity in MPAs while highlighting information needed to fully capitalize on this important ecological process for more effective and resilient MPAs.



What is connectivity and why is it important to MPAs?

Ecological connectivity, the movement of populations, individuals, genes, gametes, and propagules between populations, communities, and ecosystems, as well as that of non-living material from one location to another, is a fundamental ecological process (see Box 1). Effective **ecological networks** of MPAs are systems of core habitats connected by ecological corridors that are established, restored, and/or maintained to conserve biological diversity in systems that have been fragmented. These networks can be critical tools for sustainable ecosystem-based management. Their successful design and management depends, in part, on identifying, maintaining, and enhancing connectivity among distinct sites within the network. Enhancing ecological connectivity among MPAs improves conservation outcomes by promoting biodiversity, population persistence and resilience, increased capacity to adapt to environmental change, and sustainable fisheries management.¹⁻⁴ Well-connected networks of MPAs can also help species and ecosystems adapt to climate change by protecting climate refugia or providing a “safe landing place” for species undergoing range shifts.⁵ Ultimately, integrating ecological connectivity into the design and adaptive management of MPA networks can improve conservation outcomes at individual MPAs and throughout the network while potentially reducing the footprint of its individual protected areas.



Organisms from tiny plankton to enormous whales create and benefit from connectivity. Photo: Ed Lyman/NOAA Permit #14682-37906

Box 1: Types of Ecological Connectivity

Understanding how and which marine areas are linked ecologically is critical to maintaining their connectivity. **Passive (oceanographic) connectivity** is the movement of organisms, nutrients, and materials through physical processes like currents, sinking, or upwelling, such as the transport of larvae via ocean currents. In contrast, **active (migratory) connectivity** is the purposeful, self-directed movement of organisms from place to place, such as the migration of whales between feeding and breeding grounds or the daily vertical migrations of plankton and mesophotic species. **Habitat connectivity** is the linkage between discontinuous habitats of the same type while **seascape connectivity** is the linkage between habitats of differing types. For example, a fish living as a juvenile in mangroves that later migrates to seagrass beds and then to nearby coral reefs as an adult provides seascape connectivity between these distinct habitats. As that fish swims to adjacent reefs, it is connecting those habitats through active connectivity. If the fish releases larvae on a reef which are transported via currents to a mangrove, these habitats are connected through passive connectivity (See Figure 1). An MPA network that includes and maintains these distinct ecological linkages among habitats and life history stages for many key species may be more effective and resilient over time.²

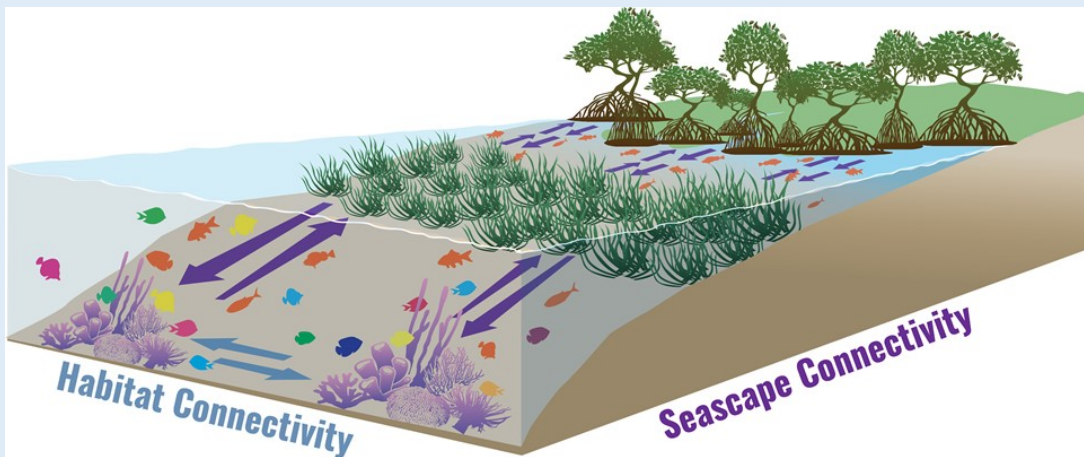


Figure 1: Seascape habitat connectivity. Fish moving between mangrove, seagrass, and coral reef habitats (purple arrows; right axis) represent seascape connectivity. Fish moving between patches of coral reef habitat (blue arrows; left axis) represent habitat connectivity. Image: NOAA

Current status of connectivity in MPA networks

Much of our understanding of connectivity in protected areas is derived from the study of terrestrial areas where the processes creating ecological connectivity can be fundamentally different from those in the ocean. The biophysical nature of the marine realm and deep seas requires the development and application of a new body of knowledge about how to best ensure connectivity is maintained in the ocean. While an increased understanding of connectivity in the ocean will surely help leverage its benefits for MPAs and the surrounding ecosystems, in many situations we already have sufficient knowledge to more fully incorporate it into MPA design and management. Despite the growing evidence of the benefits of connectivity, a recent extensive examination of the application of connectivity in MPAs found that only 11% of MPAs across six global regions explicitly considered connectivity as part of site selection, and that 71% of those were either California State MPAs or Australia's commonwealth marine reserves.⁴



Preserving connectivity can enhance ecosystem resilience by allowing for recolonization after disturbance. *Photo: NOAA*

The incorporation of connectivity into the design and management of MPAs and MPA networks presents challenges and limitations. The most robust techniques to document ecological connectivity require complex research efforts, such as genetics or tagging, that may be time- or cost-prohibitive. In addition, climate change can alter migration and larval dispersal pathways by changing ocean hydrodynamics, physiological processes, and the viability of specific habitats. Further, while the focus of connectivity in MPAs has typically been on economically important, charismatic, and/or highly mobile species (e.g., fish and marine mammals), successful implementation of measures to protect ecological connectivity will require improved knowledge of the ecology and connectivity of other species vital to ecosystem function, such as zooplankton, benthic invertebrates and plants, and other forage species. To successfully integrate connectivity into the design and management of MPAs, we must recognize these and other gaps and work to fill them.



The breeding migration of Caribbean spiny lobsters is one of the strangest displays of connectivity on Earth. *Photo: USFWS*

Existing legal authorities and policies can also present barriers to the inclusion of connectivity considerations into MPA design and management. Many marine conservation laws and regulations do not explicitly recognize connectivity as a necessary component of place-based management.⁶ However, most MPAs are part of larger protected area systems. While these sites were typically designated with little or no consideration of their ecological linkages to other MPAs, their management as part of a larger system provides an opportunity for addressing connectivity at programmatic and regional levels. Other broader conservation authorities, such as those that protect endangered or migratory species, often incorporate connectivity (e.g., migratory routes, breeding areas) as a fundamental aspect of the life histories and ecology of their target species. Modifying or leveraging such existing authorities, or creating new ones to explicitly address ecological connectivity within MPAs, would greatly enhance the inclusion of connectivity as a component of MPA establishment and management.

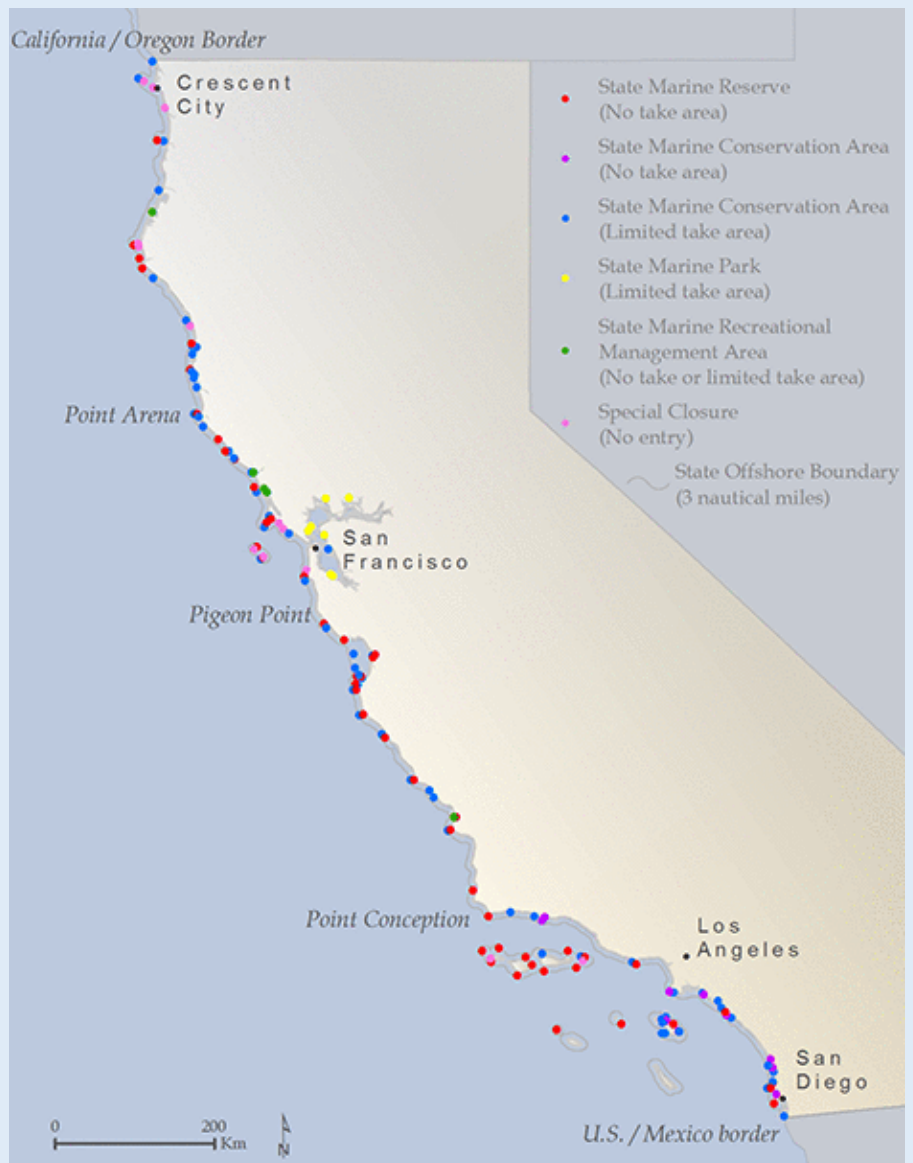
Box 2: Creating an Ecologically Connected Network in California

California's Marine Life Protection Act of 1999 directed the state to redesign its system of MPAs to function as an ecologically cohesive network.^{7,8} The state explicitly considered ecological connectivity between potential MPAs to improve design, management, and conservation outcomes. During the design process, California used models of ocean circulation, MPA size and spacing guidelines based on typical larval dispersal distances, fishery species population dynamics, and fishing effort to evaluate the projected impact of the proposed network on species abundance and fishery yields.^{8,9} This ground-breaking connectivity-driven approach allowed the network's design to optimize both conservation and economic outcomes. Further, the incorporation of ecological connectivity considerations into the management of California's MPAs continues to evolve. In 2019, expanding on a modelling effort that began in 2016, the state approved the implementation of a model-driven connectivity assessment of the network to gain a more comprehensive understanding of how protecting ecologically connected sites affects target species and community integrity.¹⁰

The state's groundbreaking connectivity science was informed by data and models derived partly from commercially and recreationally important fish species, but is careful to consider and provide benefits to the wide range of species necessary to maintain the ecological integrity of California's marine ecosystems. While the design necessarily reflects tradeoffs and considerations of socioeconomic impacts, it is founded on ecological connectivity. California's MPA network provides a robust and evolving model of how connectivity can be explicitly, effectively, and continually applied to MPAs.



The California MPA network was, in part, designed to preserve connectivity for ecologically important rockfish. *Photo: Michael Carver/NOAA*



Map of the California state MPA network. *Map: State of California*

The Path Forward on Ecological Connectivity

While the importance of ecological connectivity to MPAs is now increasingly recognized, the marine conservation community is still far from fully applying this knowledge to enhance conservation outcomes. Doing so will require a combination of enhanced legal authorities, improved messaging about the benefits of connectivity, and increased scientific understanding. Crucial steps forward include:

Strengthening Legal Authorities for Ecological Connectivity for MPA Design

To fully achieve the benefits of ecological connectivity in any MPA, agencies need the legal and policy tools to do so, including: (i) the explicit authority and support to design integrated networks of MPAs whose locations, size, and shape are informed by patterns of ecological connectivity; (ii) policy and scientific guidance to adjust the management of ocean and coastal areas that are between MPAs in ways that enhance their effective contributions to, or reduce their negative impacts on, nearby MPAs; (iii) authorities to establish corridors in the intervening areas between MPAs that allow for the connection of entire regions and the species and habitats that sustain them; and (iv) the authority to use, where appropriate, management strategies that allow for flexibility to address shifting species and ecosystems due to climate impacts.

Communicating the Benefits of Connectivity

To effectively make the case for ecologically connected MPA networks, planners, stakeholders, and decision-makers need: (i) increased public awareness and prioritization of marine connectivity, both within and outside of MPAs, to enhance the health of the marine system and the ecological services it provides; (ii) a wider range of robust case studies illustrating the benefits, challenges, and opportunities of addressing connectivity in MPAs; (iii) clear, intuitive conceptual models of how ecological connectivity works, understandable to a variety of audiences; and, (iv) simple ecosystem-specific maps and interactive models illustrating the degree, directionality, and impacts of ecological connectivity in real places relevant to proposed or existing MPAs.



Oceanographic connectivity of larvae is vital to the spread of sessile and slow moving animals. Photo: Greg McFall/NOAA



The movement of herbivorous fishes from reef to reef is important to ecosystem health. Photo: NOAA

Designing More Ecologically Connected Networks

Creating ecologically connected MPA networks will require: (i) a more robust and useful understanding of the nature and location of marine ecological corridors in time and space and how they enable connectivity among MPAs; (ii) the identification of climate change refugia and modelling of future impacts of climate change for incorporation into MPA networks; (iii) the development of new monitoring programs to demonstrate the effects of connectivity over time; and, (iv) the development of guidelines for when connectivity can be reliably determined by inference (e.g., by species presence or modelling) rather than solely through complex research efforts (e.g., genetics or tagging).

Understanding How Connectivity Works in Different Places

To advance the collective knowledge about how, where, and when ecological connectivity affects MPA resources and ecosystems, there needs to be increased understanding of: (i) the role connectivity plays in different types of ecosystems and communities; (ii) the physical and biological processes that govern connectivity across multiple spatial (e.g., benthic-pelagic coupling in the deep sea) and timescales; (iii) how different trophic levels and/or life history stages contribute to connectivity among sites; (iv) the role of ecological connectivity in understudied species important to ecosystem function; and (v) how climate change may affect the drivers and consequences of ecological connectivity in various ecosystems.



Improved understanding of the connectivity of lower trophic levels is an important information need. *Photo: Shannon Lyday/NOAA*

Conclusions

Incorporating ecological connectivity into the design and management of MPA networks offers a powerful opportunity to leverage a fundamental and wide-spread ecological process. Broadening the focus of MPAs from the protected places themselves to include the ecological processes that sustain them over time is a crucial next step towards designing more effective MPAs and conserving the ecosystem services they provide. Through the explicit incorporation of ecological connectivity into MPA planning, the ocean community can begin identifying and enhancing the ocean corridors that sustain both MPAs and their surrounding ecosystems for this and future generations.



Green sea turtles can travel thousands of miles, connecting marine areas across the ocean. *Photo: Ed Lyman/NOAA*

Other Resources

IUCN Marine Connectivity Working Group:

<http://conservationcorridor.org/ccsg/working-groups/mcwg/>

IUCN Guidelines for Conserving Connectivity through Ecological Networks and Corridors:

<http://conservationcorridor.org/ccsg/what-we-do/projects-and-activities/guidelines/>

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To view the report online visit: <https://marineprotectedareas.noaa.gov/nationalsystem/mpa-networks.html>

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Protecting ecological connectivity can promote and enhance biodiversity in MPAs. Photo: Mark Sullivan/NOAA