Connectivity:

A critical biodiversity consideration in global ocean sustainability

The relevance of connectivity for marine biodiversity has been recognised in the negotiations for a new international legally binding instrument for the conservation and sustainable use of biodiversity of areas beyond national jurisdiction. This technical brief provides evidence to support future negotiations. It explains how connectivity can be considered in negotiations on three of the four 'package elements' of the instrument: area-based tools, environmental impact assessments and technology transfer and capacity building. This technical brief provides an opportunity to consider appropriate ways to include ecological connectivity in order to support the delivery of the ecosystem approach.

Key messages

Movements of currents and migratory animals connect all parts of the ocean, making conservation and sustainable use of biodiversity beyond national jurisdiction complex and dependent on interconnectivity. Therefore, under the new instrument, the following provide potential starting points:

- Movements of biodiversity, including migratory species, can be integrated in planning and implementation of area-based management tools.
- Potential impacts from distant and localized activities are mobile and can be considered, given the highly connected nature of the marine environment.
- Environmental impact assessments can account for transboundary ecosystems and the connectivity generated by migratory species.
- Technology transfer and capacity building can have a role in strengthening monitoring of connectivity and making connectivity information available and accessible for decision making.

UN environment WCMC 40 years
gef
Marine Geospatial Ecology Lab
GOBI Global Ocean Biodiversity Initiative www.gobi.org

Acknowledgements

We kindly acknowledge the constructive feedback on this technical brief from Derek Tittensor, Steve Fletcher, Laura Friedrich, Katharina Bieberstein, Colleen Corrigan, David Johnson, William Emerson and Corli Pretorius.

The brief was organized jointly by Duke University Marine Geospatial Lab and UN Environment World Conservation Monitoring Centre (UNEP-WCMC). In particular we would like to thank and Daniel Dunn, Patrick Halpin, Guillermo Ortuño Crespo, Holly Brooks, Nina Bhola and Ruth Fletcher.

We would also like to thank GOBI for their continued technical support. GOBI is supported by the International Climate Initiative (IKI). The German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

This brief was produced under the auspices of the ABNJ Deeps Seas Project funded by the Global Environment Facility. This is a 5-year project jointly implemented by the Food and Agriculture Organization of United Nations (FAO) and United Nations Environment Programme (UN Environment) in partnership with regional fisheries bodies, Regional Seas Programmes, the fishing industry, international organziations and governments.

For further details or questions please contact: nina.bhola@unep-wcmc.org or rachael.scrimgeour@unep-wcmc.org.

Connectivity plays an important role for the health and productivity of the ocean.

Connectivity describes the interlinked nature of the ocean. Most ocean ecosystems have no obvious physical boundaries. Instead, they are defined by powerful currents that transport nutrients and small marine organisms, and by highly mobile species such as turtles, whales and tuna that can migrate across entire ocean basins for feeding and reproduction (Block et al. 2011, Farley et al. 2013). These horizontal and vertical movements connect the open ocean to coastal waters and the deep ocean, and play an important role in maintaining healthy and productive ecosystems.

Connectivity links national waters to areas beyond national jurisdiction.

These physical flows and migratory movements link national waters and exclusive economic zones to areas beyond national jurisdiction. Connectivity in the ocean provides significant benefits to societies that depend upon or use the goods and services provided by ocean ecosystems. However, it also means that our interactions with the ocean do not occur in isolation, but instead the impacts we have in one place can have consequences elsewhere. Hence, efforts to sustainably manage our marine resources, even in national contexts, require explicit consideration of areas beyond national jurisdiction.

Connectivity is a key consideration for biodiversity in areas beyond national jurisdiction.

The relevance of connectivity for marine biodiversity has been recognised in the negotiations for a new international legally binding instrument under the UN Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. The negotiations are evolving around four topics which make up the 'package', adopted by the fourth meeting the *Ad Hoc* Open-ended Informal Working group on BBNJ. These topics are now part of the discussions in the Intergovernmental Conference (IGC) for the new Implementing Agreement:

- Area-based management tools;
- Environmental impact assessments;
- Technology transfer and capacity building;
- Marine genetic resources.

The President's aid to negotiations for the second substantive session of the IGC includes connectivity among the general principles and approaches for area-based management tools and environmental impact assessments under this new instrument (https://undocs.org/A/CONF.232/2019/1).

In this technical brief

This technical brief provides concise baseline information on, and evidence for, the relevance of connectivity in the context of biodiversity beyond national jurisdiction and explains how connectivity can be considered in the negotiations around area-based tools and environmental impact assessments. The brief also addresses the role of connectivity in technology transfer and capacity building. The relevance of connectivity for the governance of marine genetic resources remains to be explored.

The following sections will:

- **a)** Describe how the ocean is connected across ecological and jurisdictional boundaries;
- **b)** Explain the socio-economic importance of connectivity;
- **c)** Illustrate the implications of connectivity for sustainable management and conservation of marine biodiversity, and;
- **d)** Highlight how connectivity should be integrated in current negotiations around biodiversity beyond national jurisdiction.

How is the ocean connected?

In the marine realm, movement between ecosystems is largely unobstructed by obvious physical boundaries. As a result, all parts of the global ocean are interconnected. There are two types of connectivity in the ocean: passive and active (See Figure 1).

Passive connectivity: marine organisms and other materials are transported across the ocean without active movement

Passive connectivity, also described as oceanographic connectivity, refers to the transportation of material such as nutrients, small marine organisms and other particles by ocean currents and processes such as sinking and upwelling. An example of passive connectivity is the dispersal of fish larvae, which are carried across large distances by ocean currents. Regional studies from the Coral Triangle and the Caribbean show that the passive movement of larvae connects fish populations between different coral reefs in the two regions (Schill et al. 2015, Treml et al. 2012). This passive movement of larvae between the reefs plays an important role in maintaining fish populations and healthy, functioning reefs.

Active connectivity: Marine animals migrate between different parts of the ocean

Active connectivity, also described as migratory connectivity, describes the movement of marine animals across the ocean and up and down through the water column. Marine mammals, seabirds, turtles and fish can travel great distances to reach specific feeding or breeding areas, moving between coastal waters and the open ocean. Many of these migratory species, including those of economic importance, spend some part of their lives in the open ocean beyond national jurisdiction (Lascelles et al. 2014). Another example of active connectivity is the daily vertical movement of fish and other marine organisms to the surface or to shallow waters at night to feed and back into deeper waters during the day. This daily movement represents the largest animal migration on Earth (Hays 2003).

Movement across ecological and jurisdictional boundaries

Movement in the ocean can occur horizontally, connecting different ocean basins and seas, and linking coastal waters with the open ocean. Movement also occurs vertically, connecting the deep sea and shallow waters. Both happen at multiple scales – local, regional, global – and across jurisdictional boundaries as currents and migratory species move through the High Seas, Exclusive Economic Zones and national waters (Harrison et al. 2018). Likewise, nutrients and particles can sink through the water column in the High Seas and be deposited on the extended continental shelf under the jurisdiction of a specific country.

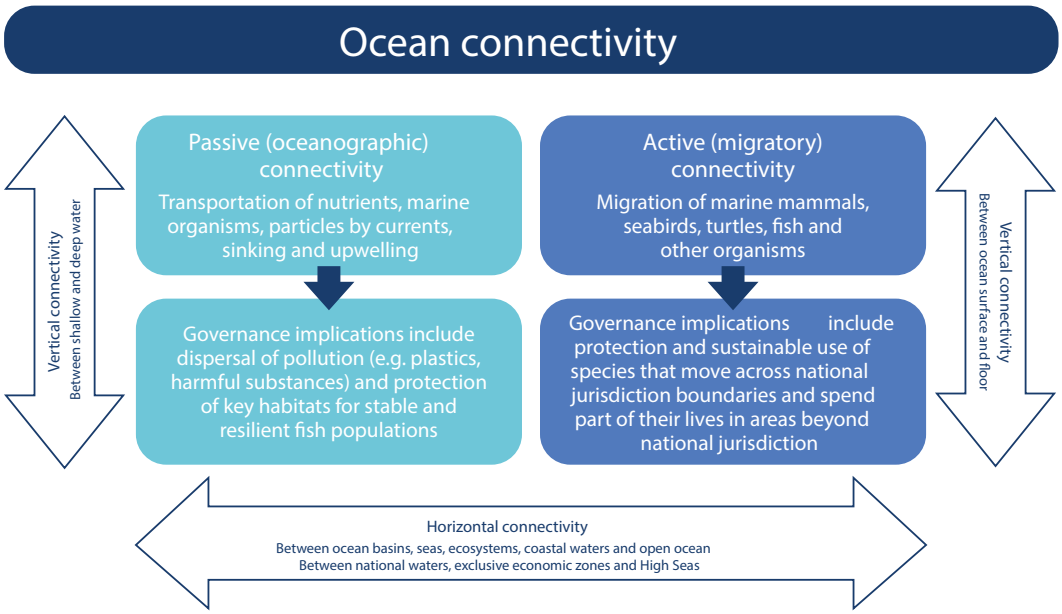

Figure 1. Illustrates the broad categories of ecological connectivity: passive and active forms of movement and the horizontal and vertical dimensions of connectivity.

What role does connectivity play?

Connectivity plays an important role for the health and productivity of the ocean and the benefits it provides to humans as ecosystem services. Through the processes described above, connectivity sustains healthy populations of marine animals and functioning ecosystems (Magris et al. 2014). Healthy and functioning ocean ecosystems provide a range of benefits for humans, including provision of food and raw materials, climate regulation, coastal protection and flood control, and acting as a source of cultural and intellectual enrichment (Lopez-Hoffman et al. 2017). The ocean and its inhabitants also play a central role in the cultures of many coastal communities. Some of these benefits are directly underpinned by connectivity. Below are two examples of the socio-economic and cultural benefits of connectivity in the ocean.

The socio-economic benefits of whale-watching

One way in which connectivity provides socio-economic benefits to coastal nations is through migratory animals, such as whales, that visit coastal waters on their annual migrations and support ecotourism industries. Whale-watching generated an average of USD $278.1 million per year throughout South America between 1998 and 2006. The whale-watching industry along the Pacific coast of South America emerged during the 1980s and early 1990s, supported by the presence of a wide range of whale species in the region (Hoyt and Iñíguez 2008).

The cultural significance of sea turtles

Many sea turtle species undertake long-distance migrations over thousands of kilometres, frequently foraging on one side of an ocean basin and nesting on the other. Sea turtles play a significant role in the cultures of many coastal communities around the world (Ripple 1996). For example, the Seri people in the Mexican state of Sonora celebrate leatherback turtles as one of their five main creators (Nabhan 2003). These turtles come to Central America to nest and afterwards travel south towards the South Pacific Gyre (Schick et al. 2013, Shillinger et al. 2011).

What are the governance implications of connectivity?

The highly migratory nature of charismatic animals like whales and sea turtles, as well as the connectivity generated by ocean currents, have significant implications for the protection and sustainable use of marine biodiversity.

Governance implications of highly migratory animals

Recognising the socio-economic value of healthy whale populations in their coastal waters, countries like Ecuador have redefined their relationship with these animals, turning away from whaling and focusing instead on the protection of whales and other cetaceans (Denkinger et al. 2013). However, many of the species that support whale-watching in the region spend only part of their lives in the national waters of South American countries (CPPS 2014, Steel et al. 2008). On their annual migrations, these whales travel into the High Seas and other national jurisdictions across the Pacific, where they face threats from pollution, underwater noise, ship strikes and exploitation.

Similarly, sea turtles cross the national jurisdictions of multiple countries as well as the High Seas on their migratory routes (Harrison et al. 2018). Along the way, their populations are heavily impacted by bycatch in fisheries, coastal development of nesting beaches, loss of eggs to invasive species and unsustainable egg harvesting. The decline in sea turtle populations has substantial consequences for many Indigenous Peoples and coastal communities, and can affect their cultural heritage, identity and livelihoods (Nabhan 2003).

Transboundary collaboration can protect migratory species through a governance framework that considers connectivity in the life cycle of these animals. To sustain benefits from migratory species, such as those discussed, management and conservation plans can include migratory patterns.

Implications of larval transportation by currents

Transportation of larvae by currents is essential to ensure that marine ecosystems remain connected, resilient and productive. For example, in coral reefs, larvae can be transported across the borders of exclusive economic zones and the High Seas. Loss or damage to a ‘source’ reef (where the larvae originate from) can lead to impacts on connected reefs which are large distances away. Larval transport can also link other marine habitat types across multiple spatial scales. Simulation studies can help to identify connectivity between reefs and other connected habitats in the open ocean. This can inform governance approaches to ensure that fish populations at these connected habitats are not damaged by impacts on ‘source’ habitats. However, since the scales of connectivity mean that these movements occur across national boundaries and the High Seas, such governance processes need multilateral agreements.

The case of marine pollution

Another key challenge for ocean governance related to the fact that the ocean's resources transcend jurisdictional boundaries is marine pollution. Most sources of pollution are land-based, with harmful substances, eroded soil, plastics and other debris making their way into the ocean through rivers for from the coasts. However, once in the ocean, currents can transport the debris and harmful substances around the world, reaching even the most isolated regions such as the Arctic (Zarfl and Matthies 2010) and deep sea trenches (Chiba et al. 2018). Ocean currents also transport oil across wide regions, making oil spills difficult to contain and resulting in consequences for regions far away from where the spill occurred (Özgökmen et al. 2016). Thus, due to the connected nature of the ocean, marine pollution is a transboundary issue of global dimensions that presents a serious threat to marine biodiversity and ecosystem services both within and beyond areas of national jurisdiction.

How can connectivity be integrated in negotiations on biodiversity beyond national jurisdiction?

Connectivity plays a key role in the implementation of area-based management tools and environmental impact assessments for the governance of biodiversity beyond national jurisdiction. This has already been recognised by the IGC for the new instrument. Moreover, understanding of connectivity could also strengthen potential outcomes on technology and capacity building (See Figure 2 below).

Area-based management tools

Area-based management tools include marine spatial planning, individual marine protected areas and networks thereof, and sectoral measures such as closure of areas to fishing, mining, navigation and/or discharge activities (https://www.unep-wcmc.org/resources-and-data/abnj-tools-review). These tools have been put forward as potential approaches for the conservation and sustainable management of biodiversity in areas beyond national jurisdiction. As stated in the Chair's overview at PrepCom 3, there is a need to define how area-based management tools and their objectives relate to the conservation and sustainable management of static and dynamic biodiversity in areas beyond national jurisdiction. In order to meet conservation objectives for biodiversity beyond national jurisdiction, passive and active connectivity need to be considered in the planning and implementation of area-based management tools.

Understanding the connectivity that migratory animals display, how and when they use different parts of the ocean, and the importance of specific sites and routes, is key for designing effective area-based conservation and management measures for these animals. Many migratory species depend on specific locations for breeding and feeding. For animals that display strong connectivity, i.e. that consistently move between a small number of sites, habitat degradation or threats to the health of the animals at a single site can result in loss of the entire population.

Several approaches have been put forward to address migratory connectivity in areas within and beyond national jurisdiction, including:

- **a)** Networks of marine protected areas that are interconnected, ecologically representative and equitably managed (Hooker et al. 2011);
- **b)** Large marine protected areas that cover an area larger than 10,000 km^2 (Wilhelm et al. 2014);
- **c)** Dynamic ocean management, where the spatial and temporal boundaries of management measures reflect changing conditions in the ocean (Maxwell et al. 2015).

Networks of marine protected areas and large marine protected areas can incorporate different sites that migratory animals use for breeding and feeding, as well as the migratory routes between these sites, by either protecting them separately, or trying to encompass them all within one very large protected area. Under dynamic ocean management, protection measures can follow the animals on their migrations and adapt to changes in conditions in the water in real time. By developing a framework that enables all three approaches, the new instrument for biodiversity beyond national jurisdiction would allow flexibility in how different scales of connectivity are conserved.

Besides knowledge of the movement patterns of migratory animals, the evidence for ocean current movements also supports efforts to prioritise areas of particular importance for regional connectivity and resilience. For example, the below studies from the Coral Triangle and the Caribbean identify coral reefs that, through passive connectivity, play a key role in maintaining stable fish populations in the region (Schill et al. 2015, Treml et al. 2012).

Environmental impact assessments

The transboundary nature of human impacts in the ocean is highly relevant for the conservation and sustainable use of biodiversity beyond national jurisdiction. The impacts of land-based activities or activities in national waters can spread to areas beyond national jurisdiction. For example, the degradation of coastal marine habitats can lead to a decline in populations of open ocean species that come to coastal waters to reproduce, mature, or feed. Conversely, activities in the High Seas can have negative consequences for coastal nations that depend on marine animals that spend at least part of their lives in areas beyond national jurisdiction, as illustrated by the example of whale-watching in South America.

To address the issue of transboundary impacts, suggestions have been put forward in the negotiations by the African Group and the Pacific Small Island Development States for the development of transboundary impact assessments as part of the new instrument for biodiversity beyond national jurisdiction (http://www.un.org/depts/los/biodiversity/prepcom.htm). These transboundary impact assessments could be implemented both for activities in areas beyond national jurisdiction and for activities in countries' Exclusive Economic Zones, and would offer an approach for monitoring the impacts of High Seas activities on coastal nations. The importance of taking into account transboundary impacts in environmental impact assessments for biodiversity beyond national jurisdiction was also emphasised in the President's aid to the second IGC.

Given the central role that connectivity plays in the transboundary distribution of impacts, the movements of ocean currents and migratory animals need to be considered in the development and implementation of these transboundary environmental impact assessments. In particular, understanding the scales and pathways of passive and active connectivity would help determine the area that should be covered by the assessments.

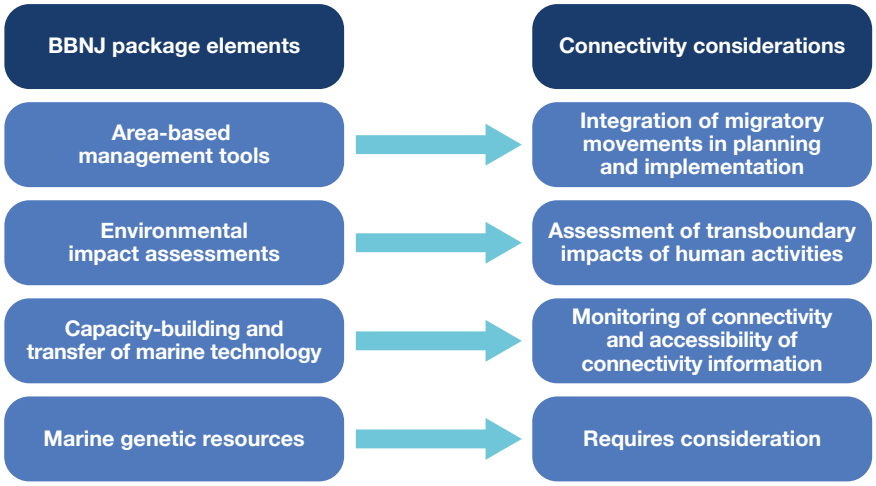

Figure 2. Summarizes how connectivity can be integrated in the package elements for an instrument for biodiversity in areas beyond national jurisdiction (BBNJ)

Technology transfer and capacity building

The importance of technology transfer and capacity building is a clear priority for many States involved in the negotiations on a new instrument for biodiversity beyond national jurisdiction, as reflected in the Chair's overview of PrepCom 2.

As illustrated in this technical brief, understanding and monitoring passive and active connectivity is important to the conservation and sustainable use of marine biodiversity beyond national jurisdiction. Ocean currents and migrating marine animals connect all parts of the ocean and coastal nations with each other. As a result of this connectivity, the success of conservation efforts in one region might depend on actions in other regions. Therefore, capacity building and technology transfer to support monitoring programmes is critical to ensure that efforts in one region are not undermined by lack of capacity in another.

Equal capacity to obtain knowledge about the ocean within and beyond national jurisdiction is also needed to implement the principles of equity and transparency that can guide the governance of the High Seas, as adopted at the IGC. Given differences in capacity for monitoring between regions and States, capacity building and technology transfer to support monitoring of connectivity, as well as minimum monitoring standards across sectoral or regional intergovernmental organizations, might be important components of the new instrument.

Capacity building is also needed to improve understanding of connectivity, especially regarding access to data and translation of this data into information for decision-making. For example, while the quantity of data on the movement of marine migratory animals has increased considerably with advances in electronic tracking technology (Block et al. 2011), access to this data is often difficult, and as a result, knowledge on how different migratory species use the ocean remains limited. Various initiatives are working on providing open online access to useable knowledge that can support the integration of connectivity in the governance of biodiversity beyond national jurisdiction. Global Fishing Watch (http://www.globalfishingwatch.org/) is using vessel tracking data from Automatic Identification Systems and Vessel Monitoring Systems to provide information about the human activities that are related to connectivity such as fishing. The Migratory Connectivity in the Ocean (MiCO; http://mico.eco/) system is pulling together knowledge on area use and movements of migratory species. The new instrument for biodiversity beyond national jurisdiction has the potential to support these advances in knowledge on connectivity in the ocean by promoting open access data sharing.

The new instrument also has the potential to increase capacity for monitoring and understanding ocean connectivity by providing structural support for the Global Ocean Observing System (GOOS). GOOS provides an integrated framework of data to inform ecosystem-based management and evidence-based conservation, supporting sustainable development and biodiversity conservation. For the conservation and sustainable use of biodiversity beyond national jurisdiction, it is essential that this evidence base includes standardised data on connectivity in the ocean.

References

Block, B.A., Jonsen, I.D., Jorgensen, S.J., Winship, A.J., and others. (2011). Tracking apex marine predator movements in a dynamic ocean. *Nature*, 475 (7354): 86-90.

Denkinger, J., Oña, J., Alarcón, D., Merlen, G., Salazar, S. and Palacios, D.M. (2013). From whaling to whale watching: cetacean presence and species diversity in the Galápagos Marine Reserve. In Science and Conservation in the Galapagos Islands (pp. 217-235). Springer, New York, NY.

Farley, J.H., Williams, A.J., Hoyle, S.D., Davies, C.R., Nicol, S.J. Reproductive dynamics and potential annual fecundity of South Pacific Albacore Tuna (*Thunnus alalunga*). PloS ONE 8(4):e60577.

Hays, G. C. (2003). A review of the adaptive significance and ecosystem consequences of zooplankton diel vertical migrations. In: Migrations and Dispersal of Marine Organisms (pp. 163-170). Springer, Dordrecht.

Hays, G.C., Mortimer, J.A., Ierodiaconou, D., Esteban, N. (2014). Use of long –distance migration patterns of an endangered species to inform conservation planning for the world's largest marine protected areas. *Conservation Biology*, 28(6): 1636-1644.

Hooker, S. K., Cañadas, A., Hyrenbach, K. D., Corrigan, C., Polovina, J. J., & Reeves, R. R. (2011). Making protected area networks effective for marine top predators. *Endangered Species Research*, 13(3): 203-218.

Hoyt, E. and Iñíguez, M. (2008). The state of whale watching in Latin America. WDCS, Chippenham, UK.

Lascelles, B., Notarbartolo Di Sciara, G., Agardy, T., Cuttelod, A., and others. (2014). Migratory marine species: their status, threats and conservation management needs. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 24(S2): 111-127.

López-Hoffman, L., Chester, C. C., Semmens, D. J., Thogmartin, W. E., and others. (2017). Ecosystem services from transborder migratory species: implications for conservation governance. *Annual Review of Environment and Resources*, 42: 509-539.

Magris, R.A., Pressey, R.L., Weeks, R. and Ban, N.C. (2014). Integrating connectivity and climate change into marine conservation planning. *Biological Conservation*, 170: 207-221.

Maxwell, S.M., Hazen, E.L., Lewison, R.L., Dunn, D.C., and others. (2015). Dynamic ocean management: Defining and conceptualizing real-time management of the ocean. *Marine Policy*, 58: 42-50.

Nabhan, G. P. (2003). Singing the turtles to sea: the Comcáac (Seri) art and science of reptiles (Vol. 3). Univ of California Press.

Özgökmen, T.M., Chassignet, E.P., Clint, N., Dawson, D.D. and others (2016). Over what area did oil and gas stread during the 2010 deepwater horizon oil spill? Oceanography 29:3.

Ripple, J. (1996). Sea turtles. Voyageur Press (MN).

Schill, S.R., Raber, G.T., Roberts, J.J., Treml, E.A., Brenner., J., Halpin, P.N. (2015). No reef is an island: Integrating coral reef connectivity data into the design of regional-scale marine protected area networks. PlosOne 10(12): e0144199.

Schick, R.S., Roberts, J.J., Eckert, S.A., Halpin, P.N. and others (2013). Pelagic movements of pacific letherback turtles (*dermochelys coriacea*) highlight the role of prey and ocean currents. Movement Ecology, 1:1.

Seminoff., J.A., Zárate, P., Coyne, M., Foley, D. G., Parker, D., Lyon, B.N., Dutton, P.H. (2008). Post-nesting migrations of Galápagos green turtles Chelonia mydas in relation to oceanographic conditions: integrating satellite telemetry with remotely sensed ocean data. Endang Species Res 4:57-72.

Shillinger GL, Swithenbank, A.M., Bailey, H., Bograd, S.J. and others (2011) Vertical and horizontal habitat preferences of post-nesting leatherback turtles in the South Pacific Ocean. Mar Ecol Prog Ser 422:275-289.

Steel, D., Garrigue, C., Poole, M., Hauser, N., and others (2008). Migratory connections between humpback whales from South Pacific breeding grounds and Antarctic feeding areas based on genotype matching. International Whaling Commission.

Treml, E.A. and Halpin, P.N (2012). Marine population connectivity identifies ecological neighbors for conservation planning in the Coral Triangle. *Conservation Letters*, 5(6): 441-449.

Wilhelm, T.A., Sheppard, C.R.C., Sheppard, A.L.S., Gaymer, C.F., Parks, J., Wagner, D., Lewis, N. (2014).. Large marine protected areas - advantages and challenges of going big. *Aquat. Conservation of Marine and Freshwater Ecosystems*, 24: 24-30.