Policy brief on MPA network design

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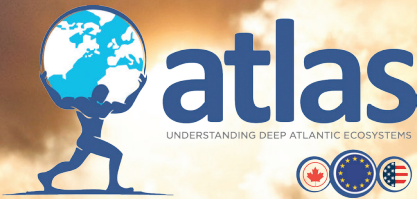
Recognising connectivity and climate change impacts as essential elements for an effective North Atlantic MPA network

Rob Tinch, Bruno Danis, David Johnson, Ellen Kenchington, Alan Fox, Sophie Arnaud-Haond, Telmo Morato, Rachel Boschen-Rose, Christopher Barrio Froján & J. Murray Roberts

Executive Summary

- MPAs can be effective tools for deep-sea ecosystem protection but their effectiveness to counter the impacts of human activities is likely compromised by climate change and ocean acidification.

- Maintaining the natural linkage between marine habitats is crucial to healthy marine ecosystems.

- Effectiveness should be considered in the context of MPA networks and connectivity.

- Area-based planning and management tools in the North Atlantic Ocean's Area Beyond National Jurisdiction already show a need for climate proofing.

- The EU-funded Horizon2020 ATLAS project is linking deep-sea connectivity, bioregions and physical parameters.

- Practical implications for the planning of MPA networks include the need to recognise marine exploited areas and deep-sea areas where biodiversity may be more resilient to climate change.

Introduction

The United Nations' Aichi Biodiversity Target for global ocean protection is 10% of the ocean in Marine Protected Areas (MPAs) by 2020[1]. However, while to date 17.3% of national waters has been protected, only 1.2% of the Area Beyond National Jurisdiction (ABNJ) is covered[2], and effective protection of this area remains a challenge[3], in part due to governance issues. Recognising this shortfall, the UN General Assembly agreed[4] in 2015 to develop an international legally binding instrument under UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ). Negotiations for the instrument cover Area-Based Management Tools (ABMTs) including MPAs.

MPAs have been shown to be effective tools for ecosystem protection if they consider basic ecological principles and set clear conservation goals[5]. There are several principles agreed by Parties to the Convention on Biological Diversity (CBD) for configuring networks of MPAs so that the level of protection afforded by the whole is much greater than the sum of the parts. The criteria for describing the CBD's Ecologically or Biologically Significant Areas (EBSAs) and for designing representative networks of MPAs were adopted by CBD in 2007[6]; these are:

Criteria for ecological/biological significance	Criteria for representative networks
Uniqueness or rarity	Ecologically and biologically significant
Special importance for life-history stages of species	(see left column) and also:
Importance for threatened, endangered or declining species and/or habitat	Representativity
Vulnerability, fragility, sensitivity, or slow recovery	Connectivity
Biological productivity	Replicated ecological features
Biological diversity	Adequate and viable sites
Naturalness	

The recognition by the CBD that marine areas are connected through space and time, both physically and through the movement of animals, reinforces the dynamic nature of the oceans. In addition, marine ecosystems, including those in the deep sea, face fundamental challenges from climate change[7], including ocean acidification[8], which may affect the future properties of contemporary ABMTs and the connectivity pathways among them[9]. It is important to understand how these connected systems may alter in response to climate change and how these alterations might influence the value and effectiveness of ABMTs, ABMT networks, and their associated management systems.

Connectivity

Connectivity is one of the CBD MPA network criteria (see above). However, there are many forms of connectivity occurring at different spatial and temporal scales in the oceans. One form of connectivity is driven by water currents, which transport water and passive particles over large distances at considerable speed, facilitating or even counteracting the movement of active adult migrants. For example, highly migratory species such as adult tunas and sea turtles use currents to travel across ocean basins, while the smaller life stages of many species, such as larvae and juveniles, become entrained in currents and can be transported over great distances. This latter form of passive dispersal is not well understood as little is known about the reproductive and dispersive strategies of most deep-water species.

The effect of ocean circulation patterns on reproductive adults and larvae also influences the genetic connectivity within a species, which is an important determinant of a species' biogeographic distribution. Many marine species are distributed over large geographic areas, often divided into distinctive populations with varying degrees of adult interaction and genetic exchange amongst them. In such situations, some sub-populations may be critical to the survival of other sub-populations if one is the primary source of young recruits for the other. The exchange of individuals among populations plays an important role in regulating population size and function, and facilitating recovery from disturbances[10].

Recognition of the types of connectivity among species and areas is therefore a critical aspect for creating effective management measures. For example, research[11] has identified a system of weakly-connected closed areas to protect sea-pen Vulnerable Marine Ecosystems (VMEs) on the Flemish Cap, illustrating the added value of assessing and modelling network properties when designing MPAs. To be meaningful, however, models need proper calibration and sufficient underlying data, which in turn requires investment in robust data systems such as the Ocean Biogeographic Information System (OBIS).

The **ATLAS** project has modelled potential connectivity pathways at a sea-basin scale and highlighted the need for more research on larval behaviour in the water column to better inform future models. Larval dispersal is regulated by complex interactions between biological and oceanographic processes[12], and between passive dispersal driven by currents only and active dispersal where larvae migrate vertically within the water column[13,14]. While larvae are generally unable to counteract the physical forces of strong horizontal currents and are transported in the prevailing flows, many have sufficient swimming ability or buoyancy control to move vertically through different water masses, often towards the surface to feed before descending to the bed to settle permanently. Consequently, such larvae will be subject to significantly different transport pathways depending on where they are in the water column and how long they stay there. **ATLAS** dispersal modelling points to more than 20-fold differences in dispersal extent between near-surface and near-bed dispersal.

The **ATLAS** project has also gathered genetic data for two reef framework-forming corals (*Lophelia pertusa* and *Madrepora oculata*) showing large differences in the pattern of connectivity of those two species despite their apparent biological similarity, strong association and similar habitat preferences along the East Atlantic. This work has shown the influence of past climate changes on the reduction and expansions of the distribution of those species and on the pattern of connectivity across large spatial and temporal scales[15]. These findings underline the need to take into account the evolutionary and biogeographic history, as well as their larval behaviour and reproductive strategy in order to understand the importance of connectivity patterns on the demography and long-term persistence of populations.

At the broadest scale, **ATLAS** researchers are describing North Atlantic bioregions, recognising significant clusters of biological community assemblages and indicator species, setting the stage for the large-scale framework within which connectivity should be considered.

Climate change and connectivity

Species connectivity patterns that respond to climate change must be considered in the design of resilient networks of MPAs[16]. The connectivity between ocean regions in the North Atlantic is controlled by large-scale circulation features (also known as large-scale forcing) that vary over time and are described by indices such as the Subpolar Gyre Index (SPGI) and the Atlantic Meridional Overturning Circulation (AMOC)[17]. In western Europe, sub-decadal variability in large-scale air-sea interactions creates different annual states of the North Atlantic Oscillation (NAO)[18] that could affect network connectivity by altering the strength and direction of westerly winds and the inflow of Atlantic waters[19]. Different methods[20] agree that a weakening of the AMOC and Labrador Sea convection during the industrial era has occurred, and is leading to surface-water freshening. This has implications for connectivity patterns in the deep sea, which can be significantly different under different oceanographic regimes[21]. **ATLAS** research has shown that over the next hundred years the AMOC is expected to slow further[22] and could push the NAO into record lows[23].

Connectivity and climate change interact. Most obviously, climate-related disturbances can change larval dispersal pathways by altering ocean hydrodynamics and inducing physiological barriers such as altered spawning times, pelagic larval durations, larval mortality and behaviour[24]. Such impacts will be felt within the next 20 years at a rate likely more rapid than many species can adapt to. This could have complex implications for marine conservation, for example if reduced larval durations enhanced larval survival but reduced connectivity. For example, in one study of fish populations[25], higher temperatures resulted in reduced planktonic duration but increased egg and larval mortality. Shifts in species distribution regimes will arise through changes in physical variables, compounded by changes in nutrients and cycling changes, pollutant toxicity increases, and reduction in plankton productivity and possible invasive species distribution or dominance[26]. At the same time, modelling suggests that availability of refugia is very limited[27].

Overall, climate change threatens the effectiveness of MPAs[28] by affecting the persistence of the populations within them. **ATLAS** research has shown that changes to the AMOC and NAO cut off larvae to unprotected deep-sea coral ecosystems

and to MPAs[29]. Additionally, **ATLAS** habitat suitability modelling predictions has shown that many cold water corals could be facing a significant reduction in their suitable habitat towards 2100, while deep-sea fish could face a poleward shift in response to climate change. Designing MPA networks without taking these predictions into account could result in major investments being made in areas that will not be fit for purpose over the next several decades[30]. For example, the identification and preservation of climate refugia areas could help preserving deep-sea biodiversity and secure food resources[31] and should perhaps also be a consideration for EBSAs and hence MPA networks[32]. However, the intensity of responses to climate change and to variations in large-scale forcing can vary widely at local scales, and there is great uncertainty in how species and their environment will change. Some marine microclimates can be robust even under extreme large-scale forcing events potentially creating spatial refuges or 'safe spaces' for species[33]. Regionally-networked marine reserves can provide routes for shifting ranges, safe 'landing zones' for colonising species, and possible refugia for those unable to move if planned with such changes in mind[34]. Consequently, while connectivity now and in the future must be considered in planning MPA networks, the lack of clear information on its current state or on predictions on how this connectivity may change should not be an impediment to management action. Instead, the best available information should be used to design MPA networks, and their management should be prepared to be highly adaptive over the coming 20-year period as connectivity assumptions can be monitored and re-evaluated. As a starting point, the Global Ocean Biodiversity Initiative (GOBI) has classified EBSAs into four categories[35] each with different applicable management measures (see Box). Type III and Type IV identify spatially and temporally dynamic EBSAs, the time frames of which could be extended to include climate change predictions. In future, it may be helpful to differentiate ABMTs recognised for mobile pelagic features (e.g., associated with oceanographic fronts) from those for sessile benthic fauna associated with fixed geomorphic features (e.g., seamounts) when addressing the variety of features.

Type I: EBSAs representing a single static feature – features that are clearly differentiated in the physical world and fixed in space and time (e.g., a coral reef or an isolated seamount)

Type II: EBSAs representing groups of static features – a set of fixed areas that represent similar features and are generally clustered in space (e.g., a chain of seamounts), where interconnectivity between the individual features is critical for the overall health and survival of the local or regional ecosystem

Type III: EBSAs representing ephemeral features – a fixed area in which, over time, portions of the area meet the defining criteria and other portions do not; the location of relevant portions may shift within the whole area over time (e.g., spawning areas for fish or feeding hotspots for seabirds)

Type IV: EBSAs representing dynamic features – persistent but mobile features of the ecosystem whose boundaries may shift due to seasonal, annual or longer-term cycles (e.g., shelf-ice edges and oceanographic fronts)

The way forward

For the ABNJ of the North Atlantic Ocean, there are over 50 area-based planning and management tools (known collectively as ABMTs) and other areas upon which future ABMTs could be based[36]. They include OSPAR-recognised MPAs, CBD EBSAs[37], and areas closed by North Atlantic Regional Fisheries Management Organisations (RFMOs) to protect VMEs. Assessment of the pressures, status and resilience of these areas found that with the exception of one area[38] all of the conservation targets could be impacted by changes in at least one of five key climate change oceanographic variables before 2050[39]. Thus, there is a clear need to address the issue of climate-proofing the developing MPA network in the North Atlantic Ocean, and to develop a set of indicators quantifying their fitness.
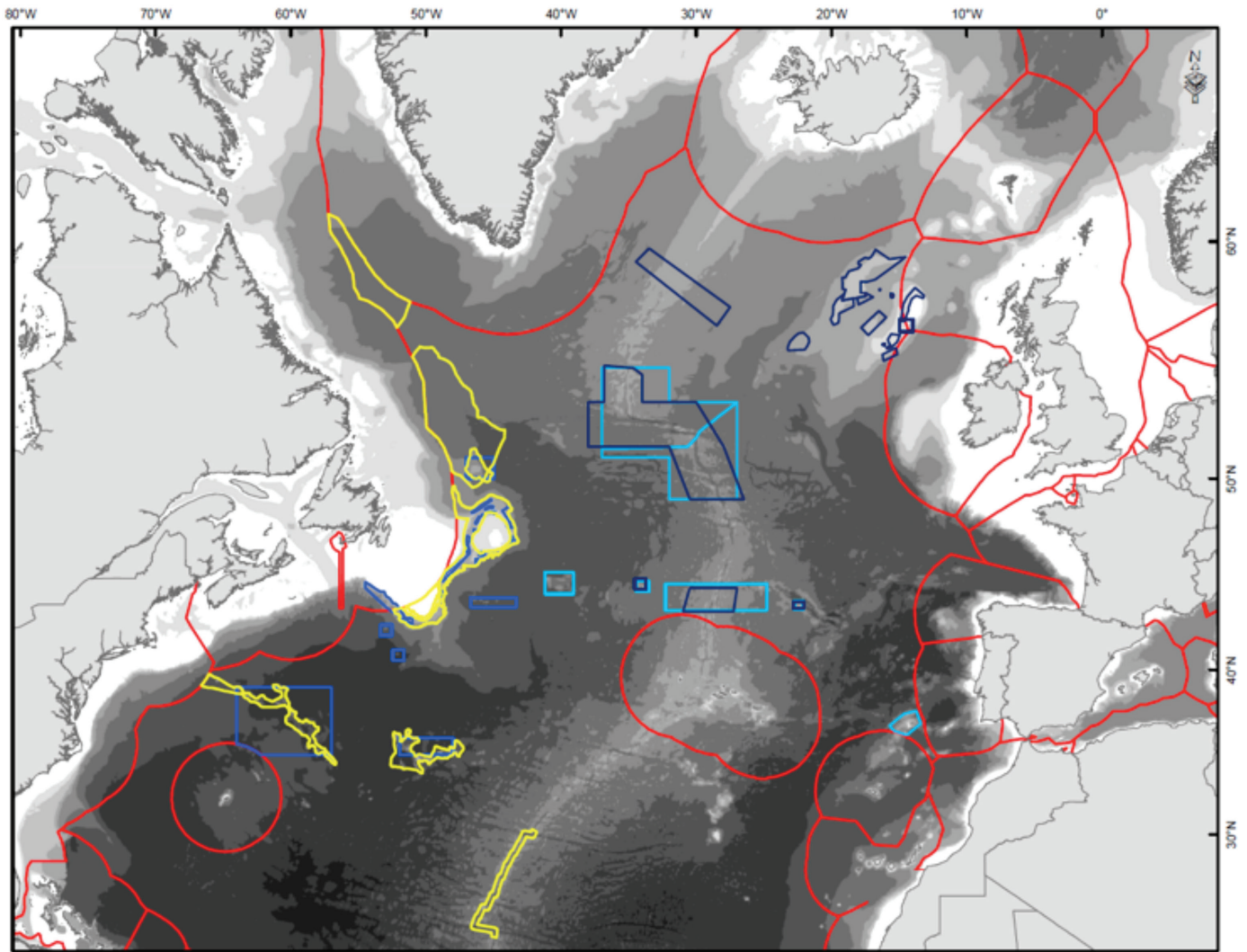
Figure 1. OSPAR MPAs, CBD EBSAs, and areas closed by RFMOs to protect VMEs in the North Atlantic ABNJ. Red lines: outer boundaries of EEZs. Light blue polygons: OSPAR MPAs; yellow polygons: CBD EBSAs; dark blue polygons: RFMO VME closures.

Given that the majority of ABMTs assessed are likely to become less fit for purpose or redundant within the next 20–50 years[40], ATLAS is exploring how connectivity matrices could be constructed. Optimisation software has been applied to try to identify the best spatial design for protecting multi-species connectivity[41]. However, four fundamental sources of uncertainty – process, measurement, model, and causal – must be considered[42].

Many marine planning studies do not use quantitative evidence to justify goals relating to connectivity or climate change directly, focusing instead on size and spacing[43]. Planning for persistence, over and above representation, is inherently more complex and requires more detailed information[44]. To evaluate priorities for ABMTs, higher resolution, smaller-scale predictions for the next two to five decades are needed[45]. The two main problems are data availability and model methodology, and the asynchrony between data/knowledge acquisition and pace of change is particularly worrying. A key challenge is developing models able to help identify tipping points to make them more robust/relevant, and applying the precautionary principle whenever possible[46]. ATLAS researchers have started to address these problems using output from a cutting-edge high-resolution ocean model (Viking20) to show statistically significant changes in bottom kinetic energy associated with the subpolar boundary currents for the NAO and AMOC[47].

One of the most important aspects to build in to network design is the connectivity among local populations of target species[48]. But in most cases MPAs will target multiple species and it is important to consider that important ecological processes may occur at different scales for different species[49]. At a basin scale, the oceans contain large physical features,

for example abyssal plains, continental shelf, continental slope and mid-ocean ridges. These features do not easily fit current EBSA or MPA designation processes. Ecosystem composition may have considerable local variability with depth and substrate, etc., but on the larger scale, similar ecosystems (e.g. cold-water coral reefs) recur. Little is known of the composition of these ecosystems, and even less about the larval behaviour, and therefore connectivity, within these large-scale features. Wide dispersal in the water column and local demersal spreading have both been observed. To guarantee the preservation of ecosystem connectivity within such features, given new estimates of the dependence of connectivity on larval behaviour and climate change coming out of ATLAS, requires maintenance of physical connection along the seabed.

Moving from a paradigm of MPAs within an exploited ocean to one of exploitation regions within a connected, protected ocean

A new concept emerging from the ATLAS consideration of spatially managed areas is to recognise that some places in ABNJ are already allocated for resource use. For deep-sea fisheries this has been described as the fishing footprint. Both North Atlantic RFMOs (NEAFC and NAFO) define areas that are subject to deep-sea fishing (these could be termed as Marine Exploitation Areas), Vulnerable Marine Ecosystems (Other Effective Conservation Measures[50] equivalent to an MPA), and other areas (exploratory fishing areas) where a precautionary approach is essential and a reverse burden of proof is appropriate with extra conditions to be met if new fishing grounds are exploited. This concept may also be suitable for other extractive industries.

In this context a problem for marine spatial planners is that regulatory regimes for marine extraction have been devised before taking a strategic environmental assessment approach and therefore networks of MPAs and/or OECMs are being retrofitted, which is unlikely to be optimal. ATLAS research has concluded that the lack of larger scale studies on impacts of anthropogenic structures[51] on marine connectivity needs to be addressed, this should integrate population genetics, larval behaviour and reproductive studies for key species.

FURTHER NOTES

The EU ATLAS project – A Trans-Atlantic Assessment and deep-water ecosystem-based spatial management plan for Europe – focuses on providing essential new knowledge of deep North Atlantic ecosystems through data gathering and synthesis, to inform and facilitate stakeholder dialogue on marine policy and regulation and to advance the European Commission's Blue Growth Strategy. One of the specific aims of ATLAS is to review the current and likely future status of ABMTs in North Atlantic ABNJ, informed by predicted shifts in ecosystem dynamics and to provide the knowledge needed to guide international conservation processes.

Area Based Management Tools (ABMTs) cover a broad range of spatial regulations providing higher protection than is given to the surrounding area "*due to more stringent regulation of one or more of all human activities, for one or more purposes*"[52]. ABMTs are often sector-specific and temporary or periodic – for example, seasonal fisheries closures. Where they achieve *in situ* biodiversity protection these have been defined by CBD as Other Effective Conservation Measures (OECM). Marine Protected Areas (MPAs) are a particular form of cross-sectoral and permanent ABMT, aiming to preserve the ecological integrity and biodiversity of marine areas over the long term, protecting ecosystem functions, species and habitats for future generations[53].

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