POLICY BRIEF

Planning and managing networks of Marine Protected Areas in a changing climate

Main findings

- **Fully protected** Marine Protected Areas (**MPAs**) are **most effective** at meeting goals **for both biodiversity conservation and fisheries**. Regulation of human activities within partially protected MPAs can achieve specific goals. **Adjacent location** of **fully and partially protected** MPAs **improves effectiveness of both**, as does greater **distance from** areas of **high human pressures**. Regulation of human activities in MPAs with intermediate human pressure or disturbance levels provides the greatest conservation gain.
- Models incorporating **within-species genetic variation of commercial fish** and structurally important algae with regional physical environmental factors **can help to explain their long-distance dispersal**. Knowledge of dispersal of species beyond MPAs and their immediate surroundings is important for effective MPA management in a changing climate.
- **Increasing sea surface temperature** in the North Atlantic has resulted in certain **algal forest species** extending **northwards** in their distribution. Isolated populations can still survive in areas of cooler upwelling in the south and these **older populations are more genetically diverse** than those at the leading edge of the range expansion. They also **support many other species** which may not be able to adapt to higher sea temperatures and thus merit protection through establishment of MPAs.

Key policy recommendations

- Include both **fully and partially protected** areas in **MPA networks** to **optimize conservation gains, regional biodiversity** and **human access. Locate fully and partially** protected areas **adjacent to each other** where possible to **increase** their **effectiveness**.
- Prioritise **full protection** for MPAs in locations with **low human pressure** to maintain **high conservation status**. Identify **specific and limited objectives** and targets for **MPAs** located **close to** areas of **high human pressures** as these are much more likely to be achieved than multiple simultaneous and over-ambitious objectives.
- **Consider long distance** (>40km) **dispersal** of **target species** as well as short distance 'spill over' effects when **designing MPA networks** and **fisheries management measures**.
- Use the **results** of **spatially explicit biophysical models** accounting for **within-species genetic diversity** to guide the design of **optimal placing, sizing and spacing of MPAs within networks**, and **fishing effort allocation** in the context of climate change.
- **Protect ancient populations** of **habitat-forming species** within **MPA networks** to help **conserve within-species genetic diversity** and **valuable habitat** which can **increase adaptability** to **climate change impacts**.

Context

European coastal and marine habitats and species provide important ecosystem, economic and social welfare benefits (e.g. fisheries, aquaculture, coastal protection, carbon storage, recreation). The value of these benefits depends on sustainable management of resources. Biodiversity is a central component of ecosystems and their services; ecologically and genetically more diverse ecosystems are more resilient to climate change impacts. Preservation of this biodiversity can be achieved using tools and policies such as designation of Marine Protected Areas at European, national and local level; management of fisheries through the EU Common Fisheries Policy (CFP); management of the wider environment through the Marine Strategy Framework Directive (MSFD) and other sectorial policies (including land-based solutions).

However, there are still gaps in the network of European Natura 2000 protected areas (EC 2016 'fitness check') and effectiveness of the network is hindered by a lack of stakeholder engagement, enforcement of regulations and effective management of sites (Assis and coworkers 2021). The 2020 European Court of Auditors report noted provisions to coordinate fisheries and marine protection policy are little used, and few available funds are used for conservation measures.

MPAs may have different objectives and varying degrees of protection: we refer to "full protection" as prohibiting all extractive uses and "partial protection" as prohibiting certain damaging activities and allowing less-damaging ones.

The 2014 update of the CFP acknowledged that some fish stocks were still being overfished and the 2020 report on implementation of the MSFD concluded the framework needs to be strengthened to tackle pressures such as overfishing and unsustainable fishing practices.

Ongoing initiatives to address such pressures include the 2021-27 European Maritime Fisheries and Aquaculture Fund[1] (EMFAF) which will have a particular focus on protecting marine ecosystems and contributing to climate change mitigation and adaptation. The EC's new Biodiversity Strategy for 2030 aims to strengthen the protection of marine ecosystems and restore them to good environmental status, including through expansion of the protected area network and establishment of strictly protected areas for recovery of habitats and fish stocks. Furthermore, a new action plan to conserve fisheries resources and protect marine ecosystems will be developed in 2021.

This brief considers how the results of some **BiodivERsA-funded research projects** can inform the next implementation cycles of European, national and local mechanisms for identifying and managing networks of protected areas post 2020. The brief specifically uses results from the RESERVEBENEFIT, MARFOR, REEF-FUTURES and BUFFER projects.

Key results

The effectiveness of MPAs depends on their management objectives, level of protection and proximity to human pressures

The effectiveness of coral reef MPAs depends on the ambition of management objectives, initial level of reef degradation and proximity to human settlements. Management can aim to achieve objectives for fisheries, ecosystem functioning and biodiversity separately or simultaneously. Where goals are to simultaneously meet all three objectives, maximal conservation gains are from fully protected MPAs in locations with low human pressure. For MPAs with lower protection levels, conservation gains peak where human pressure is intermediate. Minimal conservation gains are found where human pressure is most intense, meaning management is unlikely to enable meeting any of the MPA objectives. Biological trait diversity of fish as the measure for biodiversity was the least responsive to management[2].

MPAs worldwide include a large variety of management and zoning schemes from full to partial protection. When evaluating the effectiveness of MPAs it is important to consider the level of activity regulation within zones as well as overall MPA objectives[3].

Biomass and abundance of commercial fish species is higher in MPAs with strong regulation compared to those with weak regulation, the latter being similar to unprotected areas. Fish biomass and abundance are also high within moderately protected areas located adjacent to fully protected MPAs[4].

Fish biodiversity detected through environmental DNA analysis was very different within and outside Mediterranean no-take marine reserves and paradoxically increased with distance from the reserves. Fish biodiversity outside reserves included notably more cryptic species often missed by classical visual surveys; whereas exploited species such as bonito were found more inside reserves where they are protected[5].

1. EMFAF is due to replace the 2014-2020 European Maritime and Fisheries Fund (EMFF)
2. Cinner and coworkers 2020
3. Horta e Costa and coworkers 2016
4. Zupan and coworkers 2018
5. Boulanger and coworkers 2021

Knowledge of genetic variation and dispersal within species can assist in management of MPA networks

Estimates of dispersal distance for marine species are often limited by the geographic extent of sampling designs (actual dispersal may be much wider than the area sampled). Long-distance (>40-km) dispersal from fisheries no-take zones can provide essential benefits such as re-stocking fished areas or connecting MPAs into networks.

Oceanographic models to estimate dispersal are useful but need to be validated using knowledge of population genetics. Genomics (study of a large proportion of a species' genes rather than a few individual genes) is a useful tool to define stock estimation and estimate dispersal distances[6].

Genetic markers were identified for three species of exploited Mediterranean fish (white seabream, striped red mullet and comber)[7]. Sampling along 1,000km of coastline showed that most dispersal occurs within 10's of km, but less frequent long-distance dispersal events were observed[8].

Within-species genetic diversity of marine fish displays clear biogeographic patterns and is weakly related to species diversity. Higher fish genetic diversity was found with increasing sea surface temperature (see Figure 1).

Genetically distinct local populations may go extinct before the whole species does, resulting in the erosion of genetic diversity and adaptive potential for many species. Information on genetic diversity patterns could help in designing protected area networks and management of marine resources[9].

Many studies that consider genetic connectivity between marine reserves do not consider the environment between them. Seascape resistance models describe spatially explicit patterns and processes of connectivity across the whole seascape. 'Resistance surfaces' that might constrain movement of species or propagules (e.g. water current flow, habitat, climatic variables, bathymetry, fishing) in such models can detect significant drivers of genetic differentiation of populations within, outside and between MPAs[10].

In heavily exploited areas, a modelled network of no-take marine reserves protecting sites with high larval supply of exploited species into the population yielded highest benefit in terms of fish abundance and maintenance of larger populations outside MPAs[11].

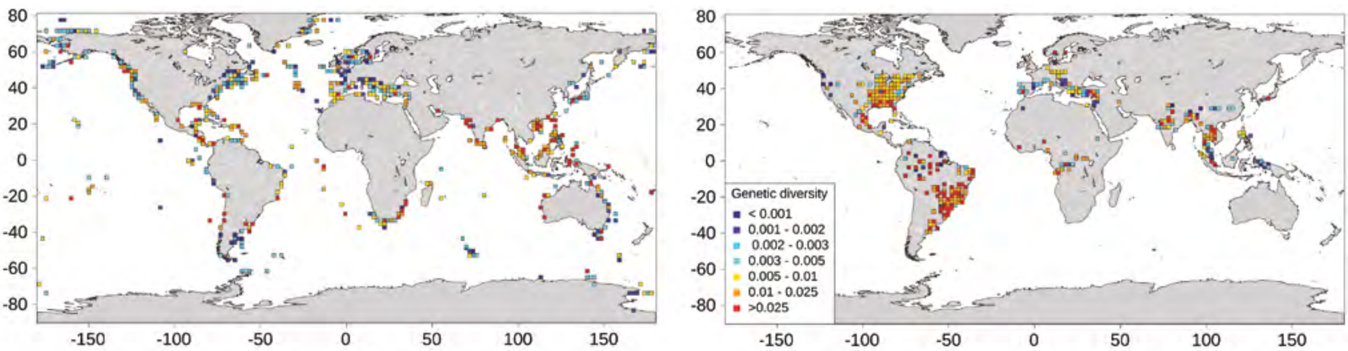

Fig. 1 Biogeographic patterns of fish genetic diversity. Higher genetic diversity was found with increasing sea surface temperature. The colour gradient represents within-species genetic diversity increasing from blue to red. (From Manel and coworkers 2020)

Climate change influences the distribution and genetic diversity of important algae

Algal populations at the edge of their distributional range are more susceptible to climate change related environmental pressures. Kelp forests are functionally important as they provide habitat which supports numerous species.

Higher genetic diversity has been found in isolated populations of golden kelp (*Laminaria ochroleuca*) from southern latitudes in deep upwelling settings, compared with populations located further north, where the species has increased its range[12]. Net loss of suitable areas was predicted for three species of *Cystoseira* seaweed; such loss is likely to have wider ecosystem impacts as there is no other species that fills the same ecological niche and functional role in the Mediterranean[13].

The resistance to, and recovery from, changes in seawater

6. Manel and coworkers 2019a
7. Fietz and coworkers 2020
8. Benestan and coworkers 2021
9. Manel and coworkers 2020
10. Manel and coworkers 2019b
11. Kininmonth and coworkers 2019
12. Assis and coworkers 2018
13. Buonomo and coworkers 2018

temperature of two marine plants (the alga *Fucus vesiculosus* and seagrass *Zostera marina*) was studied comparing northern (cold water) and southern (warm water) populations. The warm-water population of fucoid alga showed higher resistance to, and recovery from, increased temperatures, than the cold-water population. The opposite was true for the seagrass populations. Response to heat stress can vary in different populations of the same species as well as between species and is not predictable based on temperature changes alone[14].

Incorporating the reproductive period for *Sargassum muticum* into a model of its spread under two climate change scenarios considerably restricted its predicted future spread northwards. Information on reproductive cycles and factors controlling them need to be included in models to improve predictions of future distributional shifts at local and regional scales[15].

Policy recommendations

Diversify the range of **measures** used **to manage fisheries within MPA networks**; **consider long-range species dispersal** when identifying and managing MPAs and fisheries; and **improve the accuracy of models** predicting the effects of **climate change** for **functionally important** marine species.

The preparation of the 2021 action plan as part of implementing the European Commission's Biodiversity Strategy for 2030 is an opportunity to guide the development of targets and measures and promote use of tools for management of MPAs which will support and integrate both conservation of fisheries resources and protection of marine ecosystems:

- **Networks of MPAs balance conservation benefits and human access most effectively when they include both fully and partially protected** areas. Fully protected areas are more effective in achieving multiple goals. Partially protected areas allow for a range of uses and can achieve specific goals. **Location of fully protected MPAs adjacent to partially protected areas improves the performance of both**.
- When assessing the **effectiveness of networks of MPAs**, consider the **level of regulation of activities within zones of MPAs** in relation to goals set as well as overall MPA objectives.
- **Incorporate the effects of climate change** when considering **ecological effectiveness of MPA networks**, for example within **regional spatial plans**.
- **Include** specific **isolated and genetically diverse** populations of **functionally important species** such as **algal and seagrass beds and forests** in **MPA networks** to increase resilience to **climate change** impacts.
- Incorporate knowledge of **different specific responses** of **functionally important** species such as algae **and seagrasses** to **changes in sea temperature** when reviewing **resilience to climate change** in MPA networks.
- Use guidance derived from **spatially explicit biophysical models** and **within-species genetic diversity** information to guide **optimal placing, sizing and spacing of MPAs** and sustainable **fishing effort allocation**.
- When developing **fisheries management measures for MPAs at network level**, consider within-species **genetic diversity** of **fish populations**, larval supply and **isolation** and **dispersal** of species between MPAs.

14. Mota and coworkers 2018
15. Chefaoui and coworkers 2019

Links to sources

BUFFER project
RESERVEBENEFIT project
MARFOR project
REEF-FUTURES project

Scientific publications used in this policy brief can be found in the Information Sheet of this brief, downloadable from www.biodiversa.org/policybriefs

Photos: Emanuel Gonçalves

About this Policy Brief

This Policy Brief is part of a series aiming to inform policymakers on the key results of the biodiversity research projects funded by BiodivERsA and provide recommendations to policymakers based on research results.

The series of BiodivERsA Policy Briefs can be found at www.biodiversa.org/policybriefs.

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The policy recommendations made do not necessarily reflect the views of all BiodivERsA partners.

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