Evaluating whether MPA management measures meet ecological principles for effective biodiversity protection

Charlotte Rachael Hopkins[a*]

Neil M. Burns[b]

Esther Brooker[c]

Sarah Dolman[c,d]

Emilie Devenport

Calum Duncan[c,e]

David M. Bailey[f]

*Corresponding Author

[a]Department of Biological and Marine Science, University of Hull, UK

[b]Scotland's Rural College (SRUC), Edinburgh, UK

[c]Scottish Environment LINK (Marine Group), Perth, UK

[d]Whale and Dolphin Conservation (WDC), Chippenham, UK

[e]Marine Conservation Society (MCS), Edinburgh, UK

[f]Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow, UK

Abstract

Marine Protected Areas (MPAs) have been implemented as a spatial management tool throughout the world in order to meet targets for marine biodiversity conservation. The success of MPAs in achieving biodiversity conservation objectives is strongly dependent on effective management. However, evaluation frameworks for MPA management measures are often procedurally or governance focused with limited consideration of biological criteria. Here we review guiding ecological principles of MPA network design and how they can be applied to the evaluation of MPA management measures for effective biodiversity conservation. We have developed a Qualitative Statement Framework that makes recommendations for applying ecological principles to MPA management measures, using the Scottish nature conservation MPA network as a case study. Our statements to guide MPA management measure evaluation relate to principles: representation, ecologically significant areas, rare, threatened or declining features replication, connectivity, adequacy/viability and resilience. We suggest that using the ecological principles for MPA design in management measure evaluation addresses a gap in current management evaluation tools. This approach would be particularly useful in situations where management measures are applied to MPAs post-designation and where MPAs are managed as zoned or multi-use sites. Future MPA management evaluations should incorporate criteria to demonstrate how management measures meet each of the ecological principles.

Key Words: MPA management, marine protected area network, Scotland, OSPAR, ecological principles

1. Introduction

Following adoption of several international biodiversity conservation agreements, many countries have come under pressure to create networks of MPAs. As biodiversity conservation is the ostensible reason for their designation it has been common for biodiversity criteria and ecological principles to be used in site selection (e.g Australia, Environment Australia 2003, Scotland, Scottish Government 2011a, Canada, Government of Canada 2014). MPA designation does not equate to protection and at some point within the MPA implementation process, a policy decision is required on what level of protection to give to sites or zones within the sites. In attempting to also meet socio-economic objectives (including achieving fisheries targets) MPA management, in this context the measures in place that dictate the level of protection, may shift from applying the original biodiversity criteria and ecological principles. This shift can result in the weakening of the effectiveness of MPAs to conserve biodiversity (Klein et al. 2008). MPAs with the overall primary objective to conserve biodiversity cannot be considered successful unless they achieve this biological objective (Agardy et al. 2011, Fox et al. 2012, Roberts et al. 2018).

Here, we suggest a return to the guiding ecological principles for MPA networks that have the primary objective of biodiversity conservation, reviewing how these principles translate into MPA management. We have compared ecological principles across guidance from the Convention of Biological Diversity (CBD), the IUCN World Commission on Protected Areas (IUCN-WCPA) and the Oslo Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR). We have reviewed how MPA sites can be selected using the OSPAR principles for the development of an ecologically coherent network, and we present a novel framework for evaluating how these principles of MPA network design can be applied in the selection of MPA management measures. We use the Scottish Nature Conservation MPA (ncMPA) network as an illustrative case study for an initial application of this framework. We present a discussion of our findings in the context of achieving effective biodiversity conservation across an MPA network.

1.1 Principles for an Ecologically Coherent Network

To meet broad scale conservation objectives of protecting wider ecosystems, single, isolated MPAs designed and implemented in an ad-hoc manner, have been found deficient (Agardy et al. 2011). Networks of MPAs have a greater potential than individual MPAs to achieve conservation and wider ecological benefits and are widely advocated over single MPAs to address the plethora of threats facing the marine environment (Allison et al. 2003, Keller et al. 2009, Burt et al. 2014). Networks of MPAs that are well-designed and well-managed can sustain species, habitats and ecological processes across a larger geographic scale and therefore deliver on some principles of Ecosystem Based Management (EBM) (e.g. reducing cumulative impacts that compromise the delivery of ecosystem services) (Halpern et al. 2010). However, a lack of systematic conservation planning for MPA networks can lead to gaps in protection (Mora et al. 2006, Critchley et al. 2018, Fischer et al. 2018). Additionally, while MPA networks are preferable and have been widely implemented, judging whether the individual MPA sites form a coherent network remains a challenging task (Johnson et al. 2014).

The OSPAR Commission developed guidance on developing an ecologically coherent network (OSPAR Commission 2006), which aims to protect and conserve ecosystems and biological diversity, and restore areas that have been adversely affected (Table 1). The CBD COP9 (2008) adopted scientific guidance for selecting areas to establish representative networks of MPAs, including in the open ocean and deep-sea habitats (COP9/20 Annex 2). IUCN- WCPA provided a knowledge synthesis regarding designing effective MPA networks that are resilient to human and environmental threats (IUCN-WCPA 2008). Together this guidance, from OSPAR, the CBD and IUCN-WCPA, specifies that MPA networks should encompass replicated areas, representative of the species, habitats and ecosystems (including ecological processes) in a region and that the areas are ecologically connected. The core concept of an ecologically coherent network is that the constituent MPAs maintain a relationship to one another and to the surrounding environment (Smith et al. 2009).

Table 1. Aims of the OSPAR ecologically coherent network of Marine Protected Areas (MPAs).

Source: **Adapted from OSPAR Commission (2006)**

a. protect, conserve and restore species, habitats and ecological process which are adversely affected as a result of human activities

b. prevent degradation of and damage to species, habitats and ecological processes, following the precautionary principle

c. protect and conserve areas that best represent the range of species, habitats and ecological processes in the OSPAR area

Characteristics of an ecologically coherent network

1. A network's constituent parts should firstly be identified on the basis of criteria which aim to support the purpose of the network.

2. The development of an ecologically coherent network of MPAs should take account of the relationships and interactions between marine species and their environment both in the establishment of its purpose and in the criteria by which the constituent elements are identified.

3. A functioning ecologically coherent network of MPAs should interact with, and support, the wider environment as well as other MPAs although this is dependent on appropriate management to support good ecosystem health and function within and outside the MPAs.

The guiding ecological principles are intended to mitigate and reduce risk across the seascape thereby promoting resilience and increasing the likelihood that conservation objectives are achieved. However, achieving ecological coherence in the design of an MPA network should not be the intended end point. Ultimately, effective management that maintains the ecological structure and function of protected sites is needed to secure conservation objectives (Allison et al. 2003, Johnson et al. 2014). We therefore argue that the ecological principles should also apply to both MPA network design and MPA management measures if the conservation goals are to be realised.

1.2 Evaluating MPA Management

MPA designation alone is unlikely to reduce the presence of human pressure in the designated area. MPA implementation must be accompanied by effective management and regulations which address threats to biodiversity (Zupan et al. 2018). These management measures should be directed towards reducing or eliminating threats that would prevent achieving the principle biodiversity conservation objectives (Zupan et al. 2018). The achievement of these conservation objectives is dependent on many elements including MPA design, the broader context within which they are situated and their broader management encompassing governance and resource availability (Gill et al. 2017). Edgar et al. (2014) demonstrate that conservation benefits increase with the accumulation of five key features: large (>100 km^2), no-take, enforced, older and isolated. However, few MPAs are likely to comprise all five features. For example, while coastal MPAs are likely to be well enforced they are seldom also isolated.

Overall, there is considerable uncertainty surrounding when and where MPAs are the most effective in achieving biological outcomes (Woodcock et al. 2016). It is difficult to define a single best way to evaluate MPA management effectiveness (Wu et al. 2015) and as a result many methods have been proposed. As part of MPA management effectiveness evaluation, a number of indicator frameworks have been proposed (e.g. Pomeroy et al. 2005, Pajaro et al. 2010, Gallacher et al. 2016). Indicators of progress are intended to show how well MPA management is working relative to its objectives (Pajaro et al. 2010). These indicators can include biophysical, governance and socioeconomic components. As MPAs are ultimately a tool for conserving biodiversity and ecological processes, biophysical indicators are of primary importance in evaluating MPA effectiveness (Pomeroy et al. 2005).

Focal species abundance and population structure, and habitat extent are seen as more accurate determinants of whether species and habitat conservation and/or recovery is effective within the MPA and appear in multiple indicator frameworks (Batista et al. 2015, Gallacher et al. 2016). However, biophysical indicators are usually targeted at post – implementation evaluation and are dependent on a robust baseline, requiring large amounts of monitoring data that are often lacking. A qualitative statement framework approach tailored to ecological design principles may aid in the identification and evaluation of proposed or recently implemented management measures in the absence of robust baseline information or post-implementation monitoring data. This builds on current scorecard evaluation approaches, which are recommended in the absence of ecological monitoring data but are often be heavily weighted towards procedural, governance and socio-economic aspects of MPA processes (e.g. World Bank MPA scorecard (Staub and Hatziolos 2004), OSPAR scorecard (OSPAR 2007)). While good governance and positive socioeconomic factors are critically important to MPA success, ultimately the health of marine biodiversity should be the defining success factor where the objective is to protect marine biodiversity. Where we have identified a gap in evaluation approaches is early on in the MPA process, in the selection of management measures that follow ecological design principles. This evaluation step is essential as it is not practical to delay an assessment of management effectiveness until detailed post implementation data can be collected (Batista et al. 2015).

Our proposed framework is intended to enable the review of management measures in the context of guiding ecological principles for MPA network design to see if management measures are consistent with these principles. This qualitative framework is not intended to replace more detailed quantitative assessments but can aid in the evaluation of MPA management measures towards achieving biological outcomes where data is lacking for example, as part of an *a priori* approach.

2. Methods

2.1 Proposed Qualitative Statement Framework to evaluate MPA management

The CBD (CBD 2008), IUCN-WCPA (IUCN-WCPA 2008) and OSPAR (OSPAR Commission 2006) published guidance on the principles for designing an ecologically coherent MPA network. For this study we rationalised the different terminology relating to the ecological principles presented in the guidance documents (Figure 1). We then used this analysis to enable the extraction of a set of common ecological principles for MPA design (defined in Table 2.). Each of the six resultant common ecological principles were expanded into a group of qualitative statements indicating recommendations for how management measures should meet each principle. These qualitative statements were developed by reviewing the guidance for each principle in detail and determining how management measures should support delivery of the principle. An iterative discussion process among the authors resulted in the final selection of the statements in the proposed Qualitative Statement framework.

2.2 Application of the Qualitative Statement Framework to Scotland's nature conservation MPA (ncMPA) Network

We have used the Scottish ncMPA network as a case study to provide a preliminary test of the suitability of our proposed Qualitative Statement framework. The main objective of this preliminary review was to see whether the management measures in the case study could be evaluated using these statements and how well the management measures of the Scottish ncMPA network align with common ecological principles. This was achieved by collating and reviewing policy documentation from the Scottish ncMPA process on the selection of the ncMPA sites.. Policy documents for the Scottish ncMPA process were sourced from freely available material produced by Scottish Natural Heritage (SNH), Joint Nature Conservation Committee (JNCC) and Marine Scotland (Appendix A). We discuss our review of the policy documentation for the Scottish ncMPA process against our Qualitative Statement Framework in section 3.3.

Scotland's Nature Conservation MPA (ncMPA) network is a good model for testing the application of ecological principles to management as i) ncMPA sites were selected using principles related to OSPAR guidance for the development of an ecologically coherent network ii) progress towards achieving the conservation objectives of Scotland's ncMPA network has recently been reviewed (2018) and iii) management measures have been implemented for some sites, yet other ncMPA sites are without management measures. Therefore, reviewing management measures that have been implemented could immediately lead to improvements in the choice of management measures for those ncMPA sites without implemented measures.

2.2.1 Scotland's ncMPA Management

Following designation of 30 ncMPAs in July 2014, ncMPAs were split into groups to allow for phased implementation of fisheries management measures. A prioritisation document details the groupings of the phased implementation, covering the 17 inshore ncMPAs and 25 Special Areas of Conservation (SACs) (Marine Scotland 2014). The sites were prioritised generally on the presence of the most sensitive benthic habitats and species. The first phase of measures was proposed in 2014 through a series of stakeholder workshops followed by formal public consultation. The post-consultation revised measures were agreed by Scottish ministers and adopted into statutory force in 2016. Similar processes are currently underway for a second phase of inshore ncMPAs and SACs and offshore sites. Proposed fisheries measures for offshore ncMPAs and SACs must be signed off by European Member States and the European Commission. As a result, 12 ncMPAs (all inshore) have implemented management measures to date. Licensed developments and other marine activities are managed through other legislative mechanisms and therefore have limited integration with the fisheries measures implemented across the network.

3. Results

3.1 Comparison of ecological principles for MPA network design

A comparison of the ecological principles for MPA networks shows clear overlap between guidance developed by the CBD, IUCN-WCPA and OSPAR (Figure 1). We identified six core principles of MPA network design across the different sets of guidance: representation, concept for selecting areas (e.g. features, ecologically significant areas), connectivity, replication and adequacy/viability.

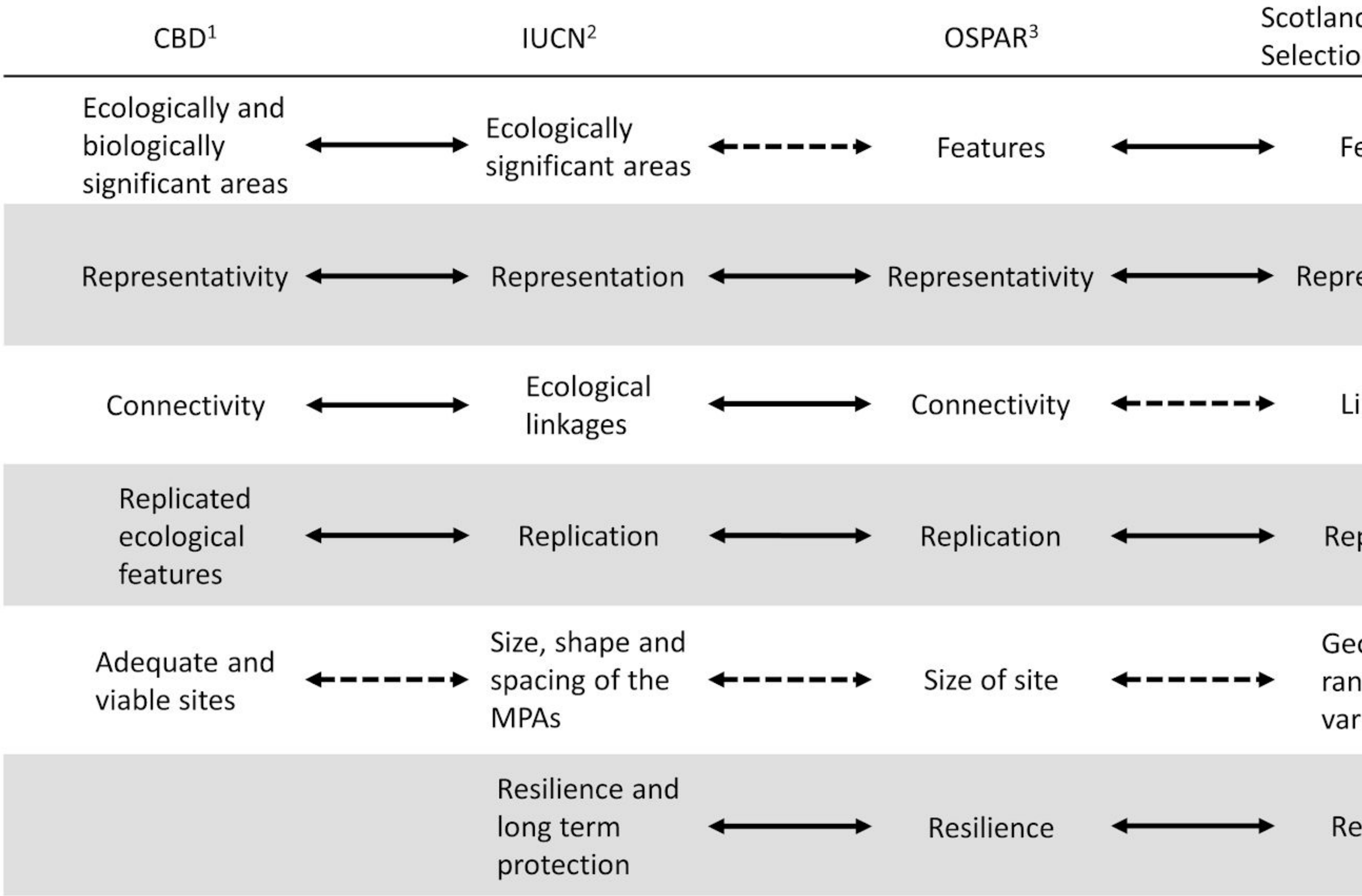

Figure 1. Relationship between the CBD, IUCN, OSPAR and Scottish ncMPA guiding ecological principles for MPA network design (adapted from Smith et al. 2009). Solid arrows indicate equivalent concepts, dashed arrows indicate related concepts. [1] (CBD 2008) [2] (IUCN-WCPA 2008) [3] (OSPAR Commission 2006) [4] (Scottish Government 2011b)

3.2 Qualitative Statement Framework for applying ecological principles to management measures

Table 2 presents a Qualitative Statement framework for evaluating to what extent the ecological principles have been applied to MPA management measures.

Table 2. Qualitative statement framework for evaluating how MPA network *management measures* meet guiding ecological principles

Principles and qualitative statements for management criteria
Principle 1: Representation - Protect the full range of biodiversity and associated oceanographic environment
Management Measure Criteria

1.1 All protected features are represented by appropriate management measures

1.2 Management measures seek to address all key threats to protected features individually and cumulatively

1.3 All protected features present in MPAs should have a conservation objective so appropriate management measures can be implemented

1.4 Characteristic or component species of a habitat or large-scale feature are protected explicitly through management measures

Principle 2: Concept for selection - ecologically significant areas, rare, threatened or declining features - Protect areas, species and habitats of unique value, high functional importance or vulnerable areas

Management Measure Criteria

2.1 Features of ecological significance or conservation concern receive greater protection

2.2 Management measures are applied to good and poor examples of feature condition across the network allowing for conservation and recovery reflecting the conservation status of the feature

2.3 Species and habitats that are under threat and/or declining have management measures that promote recovery

2.4 Management measures are proportionate to the conservation status of the feature, and precautionary where data are lacking

Principle 3: Connectivity - Ensure MPA sites are ecologically connected within the network

Management Measure Criteria

3.1 Genetic diversity and viability of features are protected under management measures in different geographical areas

3.2 Management measures protect ecological connections e.g. protection of key prey items for mobile species

3.3 Management measures protect key life stage areas for mobile species within the site for which it is designated

Principle 4: Replication - Provide replicates of all habitats and species protected to spread the risk of negative impacts across the bioregion

Management Measure Criteria

4.1 Each replicate is accompanied by effective management measures across the biogeographic range and relate to the features' conservation priorities and life history needs

4.2 Management measures are consistent relative to impacting activity on the feature across replicates within the network

Principle 5: Adequacy and viability - Ensure the size and shape of sites within the network are optimum to encompass ecological processes and maintain population integrity

Management Measure Criteria

5.1 Appropriate size of a management measure zone should be determined by the purpose of the management (e.g. conserve or recover) and be sufficiently large to maintain the integrity of the feature

5.2 Management area has a buffer zone that reflects the "conservation status" of the feature

5.3 Buffer zone is proportionate to the type of impact and seabed conditions, and the risk of impact to feature

5.4 Edge effects are minimised through appropriate size and shape of management zones (simple boundaries, straight lines, use of landmarks)

Principle 6: Resilience - Increase the resilience of desirable ecosystem states in the face of stressors (natural and anthropogenic)

Management Measure Criteria

6.1 Management measures across the whole network are adequate to protect and recover features

6.2 Management measures supports ecosystem health and function within and outside the MPAs, delivering wider ecosystem function/services

6.3 Management measures take account of climate change and changing environmental conditions and is precautionary where data is lacking

6.4 Management measures protect areas of high use as well as already minimally impacted areas

6.5 Management of the site and network as a whole allows for scientific reference areas and robust monitoring

3.3 Scottish ncMPA network case study evaluation using Qualitative Statement Framework

The following six sections discuss how the ecological principles should be applied to MPA management measures in our Qualitative Statement Framework (Table 2.) using illustrative examples from the Scottish ncMPA network.

1. Ecologically significant areas or features. There are related concepts in the CBD, IUCN-WCPA and OSPAR guidance for selecting sites. One approach is to choose areas based on habitats containing several key biodiversity elements (e.g., rare habitats, high-quality habitats, areas with multiple contiguous habitats). By protecting a diverse array of habitat types, this should conserve ecological processes and ecosystem integrity (IUCN-WCPA 2008). The OSPAR guidance is focused around a feature-based approach, whereby "*a feature is the specific aspect(s) of interest (i.e. its biodiversity or ecological character) for which a site is designated*" (OSPAR Commission 2006). However, this approach is problematic in terms of management if the feature is reduced to a particular species or habitat rather than an ecological process or biodiversity (more akin to the CBD and IUCN Ecologically Biologically Significant Areas (ESBA)). Management measures for Scottish ncMPAs were developed based on the assessment tool FEAST (**Fe**ature **A**ctivity **S**ensitivity **T**ool) (Marine Scotland 2013), an evidence-based approach to identifying the impacts that multiple marine activities and pressures have on different protected features. This approach does not consider the site as a whole, or as an

EBSA whereby interactions between pressures, cumulative impacts and the relative contribution of each pressure would need to be managed (Dunstan et al. 2016).

In the Scottish ncMPA network, 23 individual habitat features are represented within the network and 7 individual species are represented as designated features (not including replicates) (Appendix A). Of these species and habitats, 10 are present on the OSPAR threatened and declining list. Management of these species arguably requires consideration of not only direct impacts from pressures, but management measures that maintain ecosystem links and aids their recovery. Our framework proposes management measure criteria that for rare, threatened/declining species, should ensure stricter protection to enable recovery and be precautionary where data are lacking.

2. Representative. MPA networks should provide adequate representation of species and habitats across the sites within the network (McLeod et al. 2009, Gaines et al. 2010, Burt et al. 2014). Representation of species and habitats within an MPA network should only be considered adequate if accompanied by management of key threats (Zupan et al. 2018). Our framework proposes that to evaluate whether representativity has been met in terms of management measures, evaluation criteria should include whether threats have been considered both individually and cumulatively (*Criteria: 1.2*). However, the Scottish ncMPAs management measures assessment tool FEAST, does not account for intensity, frequency or cumulative impacts of pressures at a site level. Licensed developments (e.g. renewable energy, oil and gas) and other marine activities are managed through other legislative mechanisms and therefore have limited integration with the fisheries measures implemented across the network.

A key logical argument made in the defence of refined representation to a few key species and habitats is that by protecting these features, incidental protection for other species and habitats will be achieved. This concept of “umbrella species” is most often applied to species with a critical ecological function, large range or complex habitat requirements (Kalinkat et al. 2017). Marine mammals may act as umbrella species and therefore designing an MPA based around them may benefit other species (Hoyt 2008). However, if management measures for mobile species within the Scottish ncMPA network only address direct impacts (i.e. bycatch, entanglement), the measures may have little benefit to other species and habitats. The achievement of conservation objectives will be further hindered for marine mammals if management measures do not address issues relating to prey depletion and habitat loss. Overall the wider ecosystem enhancement that could be achieved by establishing effective management measures for marine mammals is likely to be low.

3. Connectivity. Connectivity can be understood as the ecological linkages between and within individual MPAs. These linkages include: movements of animals from one site to another; larval dispersal and settlement; and connections between adjacent or continuous habitat. Design of an MPA may consider habitat use within the life cycle of a species, the IUCN-WCPA guidance specifically references *"contiguous habitat systems and adjacent habitats tightly linked through the flow of matter, energy and organisms"* as an important consideration in network design (IUCN-WCPA 2008). Management using a feature-based approach, as in the Scottish ncMPA network, is unlikely to consider functionally linked habitats across a landscape. Our proposed framework includes criteria for management measures that consider the wider landscape connections (*Criteria: 3.2; 3.3*). It is important that an ecosystem-based approach to management is used that does not manage habitat or key life-stage areas in isolation, but holistically considers the wider trophic and ecosystem links and considers cumulative impacts of other human pressures (Leary et al. 2018).

OSPAR guidance is clear that assessments of connectivity should not delay the selection of sites to form an ecologically coherent network, allowing for the knowledge that data to inform these assessments is usually lacking. Although progress in assessing connectivity between MPAs is evident in recent publications (Fox et al. 2016, Foster et al. 2017), without a clear understanding of species demographics, it is not obvious how much connectivity is enough. OSPAR guidance also states that in terms of connectivity, offshore areas may be larger and further apart to encompass larger scale processes. In Scotland, the largest ncMPAs are situated offshore, in line with OSPAR guidance. However, without a clear assessment of biodiversity distribution, pressures and management effectiveness in dealing with these pressures, it is not possible to evaluate the level of connectivity between MPA sites, which is necessary to assess whether the MPAs function as a network (Krueck et al. 2017).

4. Replication. In terms of the replication principle, we propose that MPA management should be consistent relative to the impacting activity on the feature across replicates within a network (*Criteria: 4.1; 4.2*). While this seems to have been applied more consistently with fisheries measures in the Scottish ncMPA sites, variability exists in aquaculture licensing across MPA sites. Planning permission for aquaculture sites is granted by the local Planning Authority and there is some contention about the degree to which inshore sites are adequately protected from licensed activities such as aquaculture (Pautz et al. 2019).

5. Adequacy and viability. The adequacy and viability of sites to protect biodiversity incorporates considerations of site size, shape and spacing. The boundaries of ncMPAs were drawn *"as closely as possible around the feature(s)"* (Scottish Government 2011b). The same is also true for the boundaries of management measure zones within the ncMPAs, whereby management measure zone boundaries are designed as complex shapes, tied closely to the feature extent (Scottish

Government 2011b). The complexity of management measure zone shapes is counter to scientific advice that recommends simple, enforceable boundaries. This approach does not allow for appropriately sized buffer zones that allow for expansion, recovery and precautionary management of a feature, particularly in cases where a feature may be vulnerable to impacts from climate change or in the case of a species-feature, which would require suitable habitat to recover into. The complexity of management measure zone shapes also increases the edge effects of the zones raising questions over the long-term viability of the sites (Bobiles and Nakamura 2019).

6. Resilience. A key guideline from the IUCN-WCPA guidance in developing an MPA network, is the requirement for long term protection, and the understanding that no-take areas provide the greatest ecological benefit (IUCN-WCPA 2008). Incorporating these strictly protected areas is considered a foundation in most networks and a key element in ensuring resilience, the area under strict protection varying depending upon the recovery being sought and level of decline.

There is a clear indication from scientific literature that multi-use MPAs have fewer ecological benefits, and the significant proportion of Scottish ncMPAs within these lower protection categories are a cause for concern regarding the long-term capacity of the Scottish MPA network to conserve marine biodiversity. At a site level, the whole of the Scottish MPA network is designated as multi-use, variably permitting different fishing methods and human activities across the network. There are only are two small strictly protected areas within two ncMPA sites of the Scottish ncMPA network. Loch Teacuis, within the Loch Sunart to the Sound of Jura MPA has a prohibition on dredge, beam and demersal trawl, demersal seine net, set nets, lines, long lining, creels and fishing for horse mussels (1.05 km^2). North Lamlash Bay within the South Arran MPA, is the only true no take marine reserve where all forms of fishing activity are prohibited (2.66 km^2).

The Scottish Marine Atlas summarised the state of Scottish marine biodiversity prior to the designation of the ncMPAs; the majority of shelf and deep sea habitats, and many species were in decline (Baxter et al. 2011). The ecological baseline established with the Scottish Marine Atlas is now the baseline against which subsequent policy interventions are measured, but it is a baseline of an already declining and heavily impacted marine environment. Of the 127 designated features (including replicates: Appendix A), only 4 designated features (all habitat) have a conservation objective of recover. Resilience under OSPAR guidance is "*the ability an ecosystem to recover from disturbances within a reasonable timeframe*" (OSPAR Commission 2006) and recovery of the marine environment is to be achieved through the use of MPAs (OSPAR Commission 2006). Yet the limited number of recover objectives within Scottish ncMPA network seem unambitious in the context of a diminished marine environment. Furthermore, by drawing management measure boundaries tightly to the known extent of features, even given the diminished status compared to historical accounts, the network itself has not been designed with the recovery of features in mind. With management measures delineated on known feature presence, against an already diminished baseline, there is little room for recovery or range expansion and a greater risk of damage to the feature (Hopkins et al. 2016).

4. Discussion

This study was designed to provide a framework for evaluating the suitability of MPA management measures established for an MPA network that has biodiversity conservation as its primary objective. While our proposed framework does not address wider management effectiveness factors such as lack of resources and political will, which limit the implementation of systematic MPA evaluation, our proposed framework develops criteria that embeds the ecological principles for good MPA network design in the selection and implementation of management measures (Table 2). We identified a gap between MPA network design that follows guiding ecological principles and the application of these principles to MPA management measures. With growing concerns that MPAs are not truly protected, as they allow significant extractive activities that undermine biodiversity conservation (Sala et al. 2018), the need for an evaluation framework that links management measures to biological criteria is critical.

Across the guidance of the CBD, IUCN-WCPA and OSPAR for designing an ecologically coherent network, there is clear overlap and agreement on which principles constitute good design (Figure 1.). There are examples of assessing MPA network design against these principles (notably Ban et al., (2014)). However, missing from these analyses is a clear link between the ecological principles and the management measures implemented in the MPA. This could be due to differences in MPA process. For example, some MPAs are implemented with management measures, i.e. the site is chosen as a fully-protected no-take reserve, or a multi-use area as part of a wider network, or the site is designated as an MPA but without any management measures. This latter category of MPA is problematic as without management the site could become a “paper park” with no meaningful contribution towards biodiversity conservation.

MPA sites may take a zoned approach to implementing management measures, varying protection levels within the site, allowing for multi-use. Our framework particularly targets areas where management measures may be variable across the sites, as in the case of the Scottish ncMPA sites which are intended for multi-use. Our concern is that a site may be designed as part of a network to follow the ecological principles of good design, but by dividing the site into different management zones, the ecological principles are no longer applied effectively.

There is a worrying lack of MPA management effectiveness data worldwide, resulting in an inability to determine whether legal MPA designation equals genuine biodiversity protection (Roberts et al. 2018, Sala et al. 2018). Currently, it is difficult to provide systematic evaluations of management effectiveness across MPA networks. Without monitoring data to inform indicator targets on the status of species and habitats within the MPA sites, these assessments are reliant on either expert judgement or the often incomplete survey information that contributed to the selection of sites. The most commonly used protected area management effectiveness frameworks are those with an emphasis on the management process (Pyhälä et al. 2019). Most of these tools lack any assessment of the state of biodiversity or do not relate management effectiveness to conservation outcomes (Coad et al. 2015, Pyhälä et al. 2019). There is a clear link between effective MPA management performance (e.g. appropriate resources) and the achievement of ecological outcomes (Gill et al. 2017). However, within assessment tools there is little to link what may seem good management, a documented management plan and inclusion of stakeholders, which are elements of good governance, to biological processes occurring within an MPA. The impression of a well-managed network could therefore be achieved with little evidence or evaluation of achieving conservation outcomes.

While the procedural aspects of the Scottish ncMPA process for implementing management measures may score highly using tools such as the OSPAR scorecard tool (OSPAR 2007), the framework currently available for evaluating management effectiveness, a comprehensive assessment of the ecological effectiveness of management, is lacking. Adaptive management is situated within the Scottish ncMPA monitoring strategy (Marine Scotland 2017), but this needs to be based on a large amount of monitoring data to inform decision making. A risk-based approach to designing a monitoring strategy for the Scottish ncMPA network has been used with no quantitative indicators to measure what constitutes success in achieving the conservation objectives.

MPA effectiveness in ecological terms is usually measured through comparing biological indicators (sizes of organisms, density and biomass of fish assemblages, species richness and live cover of benthic organisms), to baseline information prior to MPA establishment and adjacent unprotected areas (Giakoumi et al. 2018). However, the appropriate rigour of design for these evaluations is often lacking (Giakoumi et al. 2018) and the variability in activities permitted in multi-use MPAs, will make it difficult to estimate their value in protecting biodiversity, especially in the absence of site monitoring. A mechanism for rigorous site monitoring exists in Demonstration and Research MPAs within the Scottish ncMPA process, but using these sites to enable performance assessment would need to be built into the long-term management of the MPA network.

Using frameworks that rely on qualitative judgements only are unlikely to provide an accurate evaluation of the effectiveness of MPA management. For example, in the preliminary review of Scotland's ncMPA network, our method of collating the species and habitats listed as designated features within official documents is limited in determining what constitutes adequate representation and replication of these features across the network. This method, used elsewhere, does not consider the absolute areas of habitats or sizes of populations contained within ncMPAs and therefore is it difficult to ascertain whether the long term sustainability will be achieved (Rees et al. 2018). We recommend that our proposed framework is used as a complimentary tool for MPA evaluations, but that it is does not replace more quantitative assessments and long-term monitoring of MPA networks. A further development of our proposed qualitative statement framework could be further consultation of the qualitative statements with MPA managers or to include a scoring system to be trialled with a panel of stakeholders in the structured evaluation of an MPA network.

5. Conclusions

Current assessments of progress towards achieving marine biodiversity conservation objectives are reliant on MPA area coverage targets, and although there have been substantial increases in marine area under "protection", there are persistent declines and degradation of marine species and habitats. Therefore, evaluating MPA management is critically important in assessing how effective MPAs are in conserving and recovering marine ecosystems. This study proposes a novel Qualitative Statement framework against which to evaluate how guiding ecological principles of network design are being applied to the MPA management measures. We have highlighted a gap in current management evaluation tools that are often procedurally focused and lack clear emphasis on ecological principles that must be applied to achieve conservation objectives.

Our framework is not a substitute for rigorous quantitative assessments of MPA management towards biological indicators and targets. Unfortunately, owing to budgetary constraints in protected area processes, data collection post-implementation that is required for assessments of management effectiveness, is unlikely to be prioritised and when data is collected, it is often ad-hoc and un co-ordinated (Geldmann et al. 2018). The framework proposed here is therefore likely to be useful where data is lacking, as it provides a structure for qualitative judgements to inform evaluations of MPA management plan suitability. The framework could help guide stakeholder evaluations of MPA management measures through workshops and focus groups, where experience and local knowledge can be used to evaluate the extent to which the ecological principles have been applied in local MPA management measures. In comparison to time critical, expensive quantitative data gathering, qualitative evaluations like these are more achievable because they are less expensive, can produce evaluations retrospectively and rapidly elicit results. When quantitative data is available, we suggest using our framework in combination with biological indicator frameworks to verify changes occurring as a result of MPA management.

Furthermore, our framework is particularly applicable in situations where management measures are applied to MPAs post-designation and where MPAs are managed as zoned or multi-use sites. This is because if management measures are not applied at the same time as the ecological principles to inform MPA network design, there may be a drift from these principles, resulting in less effective MPA sites. In cases where biodiversity conservation is the primary objective, this framework is also especially useful as it focuses on ecological principles rather than governance or procedural aspects that may result in a higher weighting towards socio-economic considerations. In the case of the Scottish ncMPA network, a preliminary application of the framework indicates ecological principles have been applied in the selection of ncMPA sites, but that by dividing MPAs into different management zones, some of these principles may have been weakened. Future MPA management evaluations should incorporate criteria to demonstrate how management measures meet each of the ecological principles for MPA network design.

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Appendix A. Supplementary information

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Appendix A.

Each Nature Conservation Marine Protected Areas (ncMPA) designation order for all 31 designated ncMPAs was reviewed (available from Marine Scotland website (Marine Scotland 2014)). The Loch Carrron Emergency MPA was discounted from further analysis as this site was not part of the original ncMPA selection process guided by the OSPAR ecological principles. The designated features of each MPA, the number of designated features of each MPA and the conservation objectives for those designated features was extracted from the designation orders. The type of feature was categorised in line with the designation order (e.g. mobile species, habitat etc.). The location classification of each MPA (inshore/offshore) was determined using the Scottish Government website. The origin of each ncMPA (e.g. new area, area expanded from existing protected area site) was extracted from Scottish Natural Heritage Advice to the Scottish Government (SNH 2012).

The OSPAR Threatened and Declining list (OSPAR 2008) and the Scottish Priority Marine Features (PMF) list (SNH 2014, Tyler-Walters et al. 2016) were compared against the designated features of the ncMPAs (Table A1). Search Features for MPAs and other features (that are not PMFs) but are designated features were included in the analysis of how many PMFs are designated features. How the PMFs, search features and designated features are represented and replicated within the ncMPA network was determined by analysis of MPA process documentation (SNH 2012), and cross referencing with the ncMPA designation orders.

Table A.1 Representation of Scottish Priority Marine Features (PMFs) within the ncMPA network

Priority Marine Feature (PMF)	Type	OSPAR Threatened/ Declining List	MPA Search Feature[1]	MPA se feature represe protecti measur
Blue Mussel beds	Seabed habitat	Yes	Yes	SAC/Fis
Burrowed mud	Seabed habitat	Yes	Yes	SAC
Carbonate mounds communities	Seabed habitat	Yes	Yes	SAC/Fis
Cold water coral reefs	Seabed habitat	Yes	No	n/a
Coral gardens	Seabed habitat	Yes	Yes	SAC/Fis
Deep sea sponge aggregations	Seabed habitat	Yes	Yes	-
Flame shell beds	Seabed habitat	No	Yes	-
Horse mussel beds	Seabed habitat	Yes	Yes	SAC
Inshore deep mud with burrowing heart urchins	Seabed habitat	No	Yes	SAC/Fis
Intertidal mudflats	Seabed habitat	No	No	n/a
Kelp and seaweed communities on sublittoral sediment	Seabed habitat	No	Yes	SAC
Kelp beds	Seabed habitat	No	No	n/a
Low or variable salinity habitats	Seabed habitat	No	Yes	SAC/Fis
Maerl beds	Seabed habitat	Yes	Yes	SAC
Maerl or coarse shell gravel with burrowing sea cucumbers	Seabed habitat	No	Yes	SAC
Native oysters	Seabed habitat	Yes	Yes	-
Northern sea fan and sponge communities	Seabed habitat	No	Yes	SAC
Offshore deep sea muds	Seabed habitat	No	Yes	SAC
Offshore subtidal sands and gravels	Seabed habitat	No	Yes	SAC
Seagrass beds	Seabed habitat	Yes	Yes	SAC
Sea loch egg wrack beds	Seabed habitat	No	Yes	SAC/Fis
Seamount communities	Seabed habitat	No	Yes	-
Serpulid aggregations	Seabed habitat	No	No	-
Submarine structures made by leaking gases	Seabed habitat	No	No	n/a
Tide-swept algal communities	Seabed habitat	No	Yes	SAC/Fis
Tide swept coarse sands with burrowing bivalves. (sometimes referred to as Shallow)	Seabed habitat	No	Yes	-
Burrowing sea anemone	Low or limited mobility	No	Yes	-
Pink sea fingers	Low or limited mobility	No	No	n/a
White cluster anemone	Low or limited mobility	No	No	ncMPA
Northern feather star	Low or limited mobility	No	Yes	SAC
Fan mussel	Low or limited mobility	No	Yes	Fisherie
Heart cockle	Low or limited mobility	No	Yes	-

Ocean quahog	Low or limited mobility	Yes	Yes	SAC
European spiny lobster	Mobile species	No	Yes	SAC/Fis
Eel	Mobile species	Yes	No	n/a
Atlantic salmon	Mobile species	Yes	No	n/a
European river lamprey	Mobile species	No	No	n/a
Sea lamprey	Mobile species	Yes	No	n/a
Sea trout	Mobile species	No	No	n/a
Sparling	Mobile species	No	No	n/a
Anglerfish	Mobile species	No	No	n/a
Atlantic halibut	Mobile species	No	No	n/a
Atlantic herring	Mobile species	No	No	n/a
Atlantic mackerel	Mobile species	No	No	n/a
Black scabbardfish	Mobile species	No	No	n/a
Blue ling	Mobile species	No	Yes	Area ba measur
Blue whiting	Mobile species	No	No	n/a
Cod	Mobile species	Yes	No	n/a
Greenland halibut	Mobile species	No	No	n/a
Horse mackerel	Mobile species	No	No	n/a
Ling	Mobile species	No	No	n/a
Norway pout	Mobile species	No	No	n/a
Orange roughy	Mobile species	Yes	Yes	Non are fisherie
Round-nose grenadier	Mobile species	No	No	n/a
Saithe	Mobile species	No	No	n/a
Sandeels	Mobile species	No	Yes	SAC/Fis
Sand goby	Mobile species	No	No	n/a
Whiting	Mobile species	No	No	n/a
Basking shark	Mobile species	Yes	Yes	-
Common skate	Mobile species	Yes	Yes	-
Leafscale gulper shark	Mobile species	Yes	No	n/a
Porbeagle shark	Mobile species	Yes	No	n/a
Portuguese dogfish	Mobile species	Yes	No	n/a
Sandy ray	Mobile species	No	No	n/a
Spiny dogfish	Mobile species	No	No	n/a
Atlantic white sided dolphin	Mobile species	No	No	n/a
Bottlenose dolphin	Mobile species	No	No	n/a
Fin whale	Mobile species	No	No	n/a
Harbour porpoise	Mobile species	Yes	No	n/a
Killer whale	Mobile species	No	No	n/a
Long finned pilot whale	Mobile species	No	No	n/a

Minke whale	Mobile species	No	Yes	-
Northern bottlenose whale	Mobile species	No	No	n/a
Risso's dolphin	Mobile species	No	Yes	-
Short- beaked common dolphin	Mobile species	No	No	n/a
Sowerby's beaked whale	Mobile species	No	No	n/a
Sperm whale	Mobile species	No	No	n/a
White beaked dolphin	Mobile species	No	Yes	-
Harbour/ common seal	Mobile species	No	No	n/a
Grey seal	Mobile species	No	No	n/a
Otter	Mobile species	No	No	n/a

[1] MPA search features are features of Scottish biodiversity importance for which MPAs were considered an appropriate protection measure and for which sufficient data were likely to be available.

[2] Existing network consists of protected sites including Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), designated under the Habitats Directive and the Birds Directive, and SSSIs.

Table A.2 Additional features within the Nature Conservation Marine Protected Areas (ncMPA) network not classified as Priority Marine Features (PMFs)

Additional MPA Search Features	OSPAR Threatened/ Declining List
Black guillemot	No
Continental slope	No
Fronts	No
Seamounts	Yes
Shelf banks and mounds	No
Shelf deeps	No
Other Designated Features	
Circalittoral sand and coarse sediment communities	
Marine Geomorphology of the Scottish Shelf Seabed	
Quaternary of Scotland	
Sublittoral mud and mixed sediment	
Circalittoral muddy sand communities	
Seabed Fluid and Gas Seep - pockmarks	
Submarine Mass Movement	
Marine Geomorphology of the Scottish Deep Ocean Seabed	
Polygonal fault systems	
Cenozoic structures of the Atlantic Margin	

Table A.3 Designated features within each designated Nature Conservation (ncMPA) site.

ncMPA	Designated Feature	Type of Feature	Cons
Clyde Sea Sill MPA	Black guillemot	Mobile species	Cons
Clyde Sea Sill MPA	Circalittoral and offshore sand and course sediment communities	Habitat	Cons
Clyde Sea Sill MPA	Fronts	Large scale feature	Cons
Clyde Sea Sill MPA	Marine Geomorphology of the Scottish Shelf Seabed – sand wave fields, sand ribbon fields, and sand banks	Geomorphological	Cons
East Caithness Cliffs MPA	Black guillemot	Mobile species	Cons
Fetlar to Haroldswick MPA	Black guillemot	Mobile species	Cons
Fetlar to Haroldswick MPA	Circalittoral sand and coarse sediment communities	Habitat	Cons

Fetlar to Haroldswick MPA	Horse mussel beds	Habitat	Cons
Fetlar to Haroldswick MPA	Kelp and seaweed communities on sublittoral sediment	Habitat	Cons
Fetlar to Haroldswick MPA	Maerl beds	Habitat	Cons
Fetlar to Haroldswick MPA	Shallow tide-swept coarse sands with burrowing bivalves	Habitat	Cons
Fetlar to Haroldswick MPA	Marine geomorphology of the Scottish shelf seabed	Geomorphological	Cons
Loch Creran MPA	Flame Shell Beds	Habitat	Cons
Loch Creran MPA	Quaternary of Scotland	Geomorphological	Cons
Loch Sunart MPA	Flame Shell Beds	Habitat	Cons
Loch Sunart MPA	Northern feather star aggregations on mixed substrata	Low or limited mobility species	Cons
Loch Sunart MPA	Serpulid aggregations	Habitat	Cons
Loch Sunart to the Sound of Jura MPA	Common skate	Mobile species	Cons
Loch Sunart to the Sound of Jura MPA	Quaternary of Scotland	Geomorphological	Cons
Loch Sween MPA	Burrowed mud	Habitat	Cons
Loch Sween MPA	Maerl beds	Habitat	Cons
Loch Sween MPA	Native oysters	Habitat	Cons
Loch Sween MPA	Sublittoral mud and mixed sediment communities	Habitat	Cons
Lochs Duich, Long and Alsh MPA	Burrowed mud	Habitat	Cons
Lochs Duich, Long and Alsh MPA	Flame Shell Beds	Habitat	Cons
Monach Isles MPA	Black guillemot	Mobile species	Cons
Monach Isles MPA	Marine geomorphology of the Scottish shelf seabed	Geomorphological	Cons
Monach Isles MPA	Quaternary of Scotland – landscape of areal glacial scour	Geomorphological	Cons
Mousa to Boddam MPA	Sandeels	Mobile species	Cons
Mousa to Boddam MPA	Marine geomorphology of the Scottish shelf seabed	Geomorphological	Cons
Noss Head MPA	Horse mussel beds	Habitat	Cons
Papa Westray MPA	Black guillemot	Mobile species	Cons
Papa Westray MPA	Marine geomorphology of the Scottish shelf seabed – sand wave field	Geomorphological	Cons
Small Isles MPA	Black guillemot	Mobile species	Cons
Small Isles MPA	Burrowed mud	Habitat	Cons
Small Isles MPA	Circalittoral sand and mud communities	Habitat	Cons
Small Isles MPA	Fan mussel aggregations	Habitat	Cons
Small Isles MPA	Horse mussel beds	Habitat	Cons
Small Isles MPA	Northern feather star aggregations on mixed substrata	Low or limited mobility species	Cons
Small Isles MPA	Northern sea fan and sponge communities	Habitat	Cons
Small Isles MPA	Shelf deeps	Large scale feature	Cons
Small Isles MPA	White cluster anemones	Low or limited mobility species	Cons

Small Isles MPA	Quaternary of Scotland – glaciated channels/troughs, glacial lineations, meltwater channels, moraines, streamlined bedforms	Geomorphological	Cons
South Arran MPA	Burrowed mud	Habitat	Cons
South Arran MPA	Kelp and seaweed communities on sublittoral sediment	Habitat	Cons
South Arran MPA	Maerl beds	Habitat	Reco
South Arran MPA	Maerl or coarse shell gravel with burrowing sea cucumbers	Habitat	Cons
South Arran MPA	Ocean quahog aggregations	Low or limited mobility species	Cons
South Arran MPA	Seagrass beds	Habitat	Cons
South Arran MPA	Shallow tide-swept coarse sands with burrowing bivalves	Habitat	Cons
Upper Loch Fyne and Loch Goil MPA	Burrowed mud	Habitat	Cons
Upper Loch Fyne and Loch Goil MPA	Flame Shell Beds	Habitat	Reco
Upper Loch Fyne and Loch Goil MPA	Horse mussel beds	Habitat	Cons
Upper Loch Fyne and Loch Goil MPA	Ocean quahog aggregations	Low or limited mobility species	Cons
Upper Loch Fyne and Loch Goil MPA	Sublittoral mud and specific mixed sediment communities	Habitat	Cons
Wester Ross MPA	Burrowed mud	Habitat	Cons
Wester Ross MPA	Circalittoral muddy sand communities	Habitat	Cons
Wester Ross MPA	Flame Shell Beds	Habitat	Reco
Wester Ross MPA	Kelp and seaweed communities on sublittoral sediment	Habitat	Cons
Wester Ross MPA	Maerl beds	Habitat	Reco
Wester Ross MPA	Maerl or coarse shell gravel with burrowing sea cucumbers	Habitat	Cons
Wester Ross MPA	Northern feather star aggregations on mixed substrata	Low or limited mobility species	Cons
Wester Ross MPA	Marine geomorphology of the Scottish shelf seabed – banks of unknown substrate	Geomorphological	Cons
Wester Ross MPA	Quaternary of Scotland – glaciated channels/troughs, megascale glacial lineations, moraines	Geomorphological	Cons
Wester Ross MPA	Seabed fluid and gas seep – pockmarks	Geomorphological	Cons
Wester Ross MPA	Submarine Mass Movement - slide scars	Geomorphological	Cons
Wyre and Rousay Sounds MPA	Kelp and seaweed communities on sublittoral sediment	Habitat	Cons
Wyre and Rousay Sounds MPA	Maerl beds	Habitat	Cons
Wyre and Rousay Sounds MPA	Marine geomorphology of the Scottish shelf seabed	Geomorphological	Cons
Central Fladen	Burrowed mud	Habitat	Cons
Central Fladen	Quaternary of Scotland - sub glacial tunnel valley	Geomorphological	Cons
East of Gannet and Montrose Fields	Ocean quahog aggregations	Low or limited mobility species	Cons
East of Gannet and Montrose Fields	Offshore subtidal sands and gravels	Habitat	Cons

East of Gannet and Montrose Fields	Offshore deep sea muds	Habitat	Cons
Faroe-Shetland Sponge Belt	Deep sea sponge aggregations	Habitat	Cons
Faroe-Shetland Sponge Belt	Offshore subtidal sands and gravels	Habitat	Cons
Faroe-Shetland Sponge Belt	Ocean quahog aggregations	Low or limited mobility species	Cons
Faroe-Shetland Sponge Belt	Continental slope	Large scale feature	Cons
Faroe-Shetland Sponge Belt	Quaternary of Scotland - continental slope channels; iceberg ploughmark fields, prograding wedges	Geomorphological	Cons
Faroe-Shetland Sponge Belt	Submarine Mass Movement - slide deposits	Geomorphological	Cons
Faroe-Shetland Sponge Belt	Marine Geomorphology of the Scottish Deep Ocean Seabed - sand wave fields, sediment wave fields	Geomorphological	Cons
Faroe-Shetland Sponge Belt	Marine Geomorphology of the Scottish Shelf Seabed – sand bank, sand wave fields, sediment wave fields	Geomorphological	Cons
Firth of Forth Banks Complex	Ocean quahog aggregations	Low or limited mobility species	Cons
Firth of Forth Banks Complex	Offshore subtidal sands and gravels	Habitat	Cons
Firth of Forth Banks Complex	Shelf banks and mounds	Large scale feature	Cons
Firth of Forth Banks Complex	Quaternary of Scotland – moraines	Geomorphological	Cons
Geike Slide and Hebridean Slope	Burrowed mud	Habitat	Cons
Geike Slide and Hebridean Slope	Offshore subtidal sands and gravels	Habitat	Cons
Geike Slide and Hebridean Slope	Continental slope	Large scale feature	Cons
Geike Slide and Hebridean Slope	Submarine Mass Movement - slide deposits, slide scars	Geomorphological	Cons
Geike Slide and Hebridean Slope	Offshore deep sea muds	Habitat	Cons
Hatton-Rockall Basin	Deep sea sponge aggregations	Habitat	Cons
Hatton-Rockall Basin	Offshore deep sea muds	Habitat	Cons
Hatton-Rockall Basin	Marine Geomorphology of the Scottish Deep Ocean Seabed – sediment drifts	Geomorphological	Cons
Hatton-Rockall Basin	Polygonal fault systems	Geomorphological	Cons
North-east Faroe Shetland Channel	Deep sea sponge aggregations	Habitat	Cons
North-east Faroe Shetland Channel	Offshore deep sea muds	Habitat	Cons
North-east Faroe Shetland Channel	Offshore subtidal sands and gravels	Habitat	Cons
North-east Faroe Shetland Channel	Continental slope	Large scale feature	Cons
North-east Faroe Shetland Channel	Quaternary of Scotland - prograding wedge	Geomorphological	Cons
North-east Faroe Shetland Channel	Submarine Mass Movement - slide deposits	Geomorphological	Cons
North-east Faroe Shetland Channel	Marine Geomorphology of the Scottish Deep Ocean Seabed - contourite sand/silt;	Geomorphological	Cons
North-east Faroe Shetland Channel	Cenozoic Structures of the Atlantic Margin - mud diapirs	Geological	Cons
North-west Orkney	Sandeels	Mobile species	Cons
North-west Orkney	Marine Geomorphology of the Scottish Shelf Seabed – sand bank, sand wave fields, sediment wave fields	Geomorphological	Cons

Norwegian Sediment Boundary Plain	Ocean quahog aggregations	Low or limited mobility species	Cons
Norwegian Sediment Boundary Plain	Offshore subtidal sands and gravels representing sediment types suitable for Ocean quahog colonisation	Habitat	Cons
Rosemary Bank Seamount	Deep sea sponge aggregations	Habitat	Cons
Rosemary Bank Seamount	Seamount communities	Habitat	Cons
Rosemary Bank Seamount	Seamounts	Large scale feature	Cons
Rosemary Bank Seamount	Quaternary of Scotland - iceberg ploughmark field	Geomorphological	Cons
Rosemary Bank Seamount	Submarine Mass Movement - slide scars	Geomorphological	Cons
Rosemary Bank Seamount	Marine Geomorphology of the Scottish Deep Ocean Seabed - scour moats, sediment drifts, sediment wave fields	Geomorphological	Cons
Rosemary Bank Seamount	Cenozoic Structures of the Atlantic Margin - Rosemary Bank Seamount	Geological	Cons
The Barra Fan and Hebrides Terrace Seamount	Burrowed mud	Habitat	Cons
The Barra Fan and Hebrides Terrace Seamount	Offshore subtidal sands and gravels	Habitat	Cons
The Barra Fan and Hebrides Terrace Seamount	Offshore deep sea muds	Habitat	Cons
The Barra Fan and Hebrides Terrace Seamount	Orange roughy	Mobile species	Cons
The Barra Fan and Hebrides Terrace Seamount	Seamount communities	Habitat	Cons
The Barra Fan and Hebrides Terrace Seamount	Continental slope	Large scale feature	Cons
The Barra Fan and Hebrides Terrace Seamount	Seamounts	Large scale feature	Cons
The Barra Fan and Hebrides Terrace Seamount	Quaternary of Scotland - iceberg ploughmark field, prograding wedges	Geomorphological	Cons
The Barra Fan and Hebrides Terrace Seamount	Submarine Mass Movement - continental slope turbidite canyons, slide deposits	Geomorphological	Cons
The Barra Fan and Hebrides Terrace Seamount	Marine Geomorphology of the Scottish Deep Ocean Seabed - scour moat	Geomorphological	Cons
The Barra Fan and Hebrides Terrace Seamount	Cenozoic Structures of the Atlantic Margin - continental slope, Hebrides Terrace Seamount	Geological	Cons
Turbot Bank	Sandeels	Mobile species	Cons
West Shetland Shelf	Offshore subtidal sands and gravels	Habitat	Cons

Table A.4 Nature Conservation Marine Protected Area (ncMPA) site origin (e.g. enhancement to existing protected area, enhancement to other area-based measures, new area, 3rd party proposal, a "Least Damaged/More Natural) as extracted from SNH (2012)

Nature Conservation Marine Protected Area (ncMPA)	Location	Origin[1]	New Area	Least Damaged More Natural (LDMN)	Existing Protected Area
Clyde Sea Sill MPA	Inshore	Other area based	0	0	0
East Caithness Cliffs MPA	Inshore	Existing Protected Area	0	0	1
Fetlar to Haroldswick MPA	Inshore	Existing Protected Area	0	0	1
Loch Creran MPA	Inshore	Existing Protected Area	0	0	1
Loch Sunart MPA	Inshore	Existing Protected Area; 3rd Party	0	0	1
Loch Sunart to the Sound of Jura MPA	Inshore	New area; 3rd Party	1	0	0
Loch Sween MPA	Inshore	Other area based; LDMN; 3rd Party	0	1	0
Lochs Duich, Long and Alsh MPA	Inshore	Existing Protected Area; LDMN	0	1	1
Monach Isles MPA	Inshore	Existing Protected Area	0	0	1
Mousa to Boddam MPA	Inshore	Existing Protected Area	0	0	1
Noss Head MPA	Inshore	Other area based	0	0	0
Papa Westray MPA	Inshore	Existing Protected Area	0	0	1
Small Isles MPA	Inshore	Existing Protected Area	0	0	1
South Arran MPA	Inshore	Other area based*	0	0	0
Upper Loch Fyne and Loch Goil MPA	Inshore	Other area based	0	0	0
Wester Ross MPA	Inshore	Other area based	0	0	0
Wyre and Rousay Sounds MPA	Inshore	New area	1	0	0
Central Fladen	Offshore	New area	1	0	0
East of Gannet and Montrose Fields	Offshore	LDMN	0	1	0
Faroe-Shetland Sponge Belt	Offshore	LDMN	0	1	0
Firth of Forth Banks Complex	Offshore	LDMN; Other area based	0	1	0
Geike Slide and Hebridean Slope	Offshore	Other area based; LDMN	0	1	0
Hatton-Rockall Basin	Offshore	LDMN	0	1	0
North-east Faroe Shetland Channel	Offshore	LDMN	0	1	0
North-west Orkney	Offshore	New area	1	0	0
Norwegian Sediment Boundary Plain	Offshore	LDMN	0	1	0
Rosemary Bank Seamount	Offshore	Other area based; LDMN	0	1	0
The Barra Fan and Hebrides Terrace Seamount	Offshore	Other area based; LDMN	0	1	0
Turbot Bank	Offshore	New area	1	0	0
West Shetland Shelf	Offshore	Other area based	0	0	0
Counts of Site by Origin[2]			**5**	**11**	**9**

*Not considered an enhancement because of the difference in scale between the fisheries restriction and the resultant MPA proposal

[1] Origin includes the following definitions: existing protected area – includes area that is already designated as protected under different legislation; new area – no existing protective measures are in place; other area based – includes area that is protected under different spatial measures e.g. fisheries closures; LDMN – Least Damaged/More Natural – an area that is considered to have minimal human disturbance; 3rd party proposal – locations proposed by other groups not including SNH, JNCC and Marine Scotland

[2] Includes counts of areas that may have more than one origin

Table A.5 Status of management measures for designated sites in the Scottish ncMPA network including: awaiting inshore management measures; managed under Fisheries Order; managed under Marine Conservation Order and awaiting EU formal negotiation

MPA	Code	Location	Management Status
Clyde Sea Sill MPA	CSS	Inshore	Awaiting inshore management measures
East Caithness Cliffs MPA	ECC	Inshore	Awaiting inshore management measures
Fetlar to Haroldswick MPA	FTH	Inshore	Awaiting inshore management measures
Loch Creran MPA	LCR	Inshore	Fisheries Order
Loch Sunart MPA	LSU	Inshore	Fisheries Order
Loch Sunart to the Sound of Jura MPA	SJU	Inshore	Marine Conservation Order
Loch Sween MPA	LSW	Inshore	Fisheries Order
Lochs Duich, Long and Alsh MPA	DLA	Inshore	Fisheries Order
Monach Isles MPA	MOI	Inshore	Awaiting inshore management measures
Mousa to Boddam MPA	MTB	Inshore	Awaiting inshore management measures
Noss Head MPA	NOH	Inshore	Fisheries Order
Papa Westray MPA	PWJ	Inshore	Awaiting inshore management measures
Small Isles MPA	SMI	Inshore	Reconsulting on Marine Conservation Order
South Arran MPA	ARR	Inshore	Marine Conservation Order
Upper Loch Fyne and Loch Goil MPA	LFG	Inshore	Fisheries Order
Wester Ross MPA	WER	Inshore	Marine Conservation Order
Wyre and Rousay Sounds MPA	WYR	Inshore	Fisheries Order
Central Fladen	CFL	Offshore	Awaiting EU formal negotiation
East of Gannet and Montrose Fields	EGM	Offshore	Awaiting EU formal negotiation
Faroe-Shetland Sponge Belt	FSS	Offshore	Awaiting EU formal negotiation
Firth of Forth Banks Complex	FOF	Offshore	Awaiting EU formal negotiation
Geike Slide and Hebridean Slope	GSH	Offshore	Awaiting EU formal negotiation
Hatton-Rockall Basin	HRB	Offshore	Awaiting EU formal negotiation
North-east Faroe Shetland Channel	NEF	Offshore	Awaiting EU formal negotiation
North-west Orkney	NOW	Offshore	Awaiting EU formal negotiation
Norwegian Sediment Boundary Plain	NSP	Offshore	Awaiting EU formal negotiation

Rosemary Bank Seamount	RBS	Offshore	Awaiting EU formal negotiation
The Barra Fan and Hebrides Terrace Seamount	BHT	Offshore	Awaiting EU formal negotiation
Turbot Bank	TBB	Offshore	Awaiting EU formal negotiation
West Shetland Shelf	WSS	Offshore	Awaiting EU formal negotiation

Appendix A. References

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