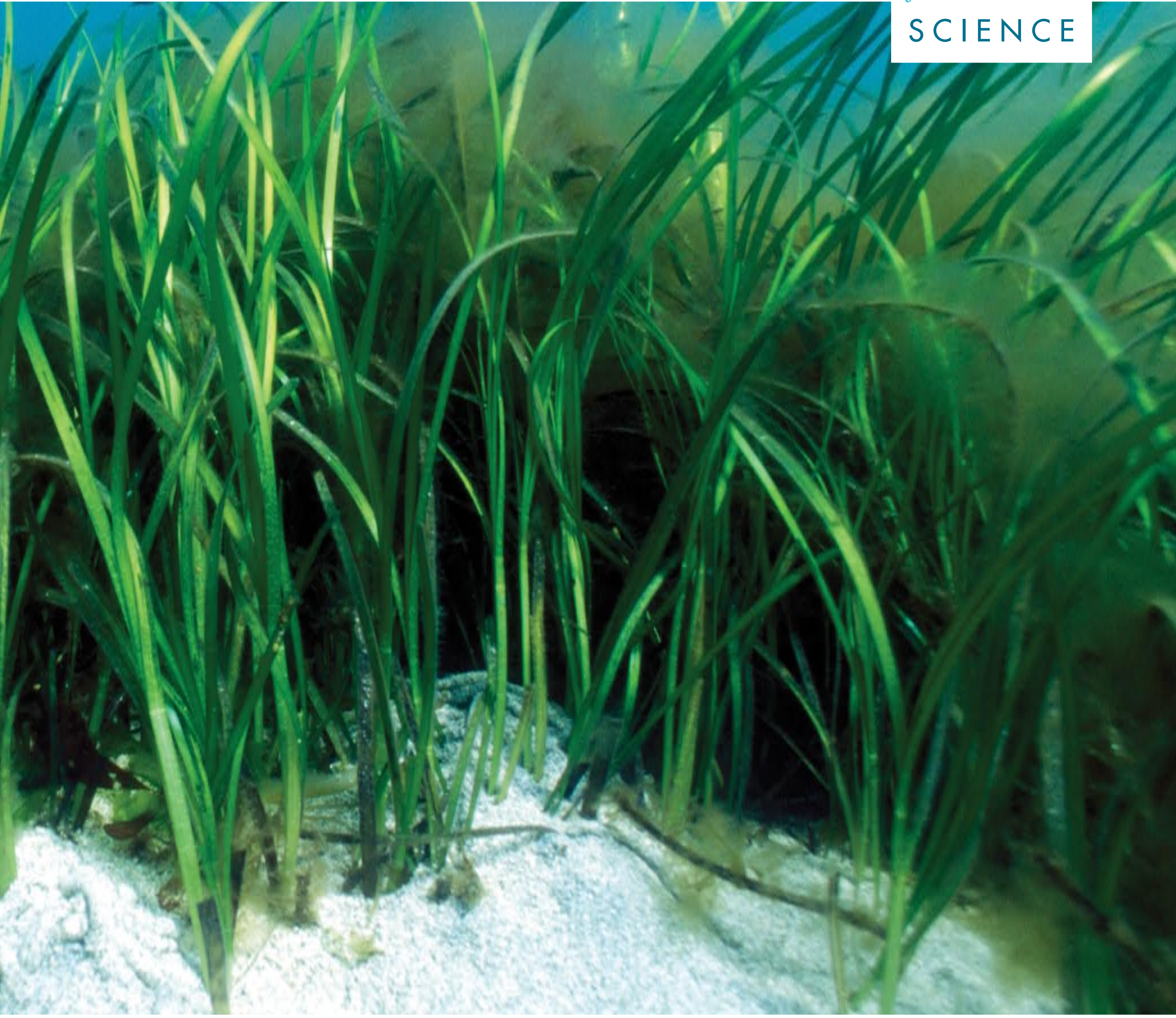
Making the case for the sound management of Marine Protected Areas

SCOTTISH ASSOCIATION *for* MARINE SCIENCE



A Report to Scottish Environment LINK




CREDITS

Report to LINK: ***Making the case for the sound management of Marine Protected Areas*** by Scottish Association for Marine Science

(See http://www.scotlink.org)

Compiled by: Elanor Bell, Ruth Brennan, Thom Nickell, Tavis Potts, Branka Valcic, Helen Wilson

Scottish Association for Marine Science
Scottish Marine Institute
Oban, Argyll PA37 1QA
Scotland, UK

Scottish Environment LINK's Marine Taskforce comprises of the following organisations:

- Hebridean Whale and Dolphin Trust
- Marine Conservation Society
- National Trust for Scotland
- RSPB Scotland
- Scottish Wildlife Trust
- WWF Scotland
- Whale and Dolphin Conservation Society

Photo credits:
Dolphin © Nicola Hodgins
Black guillemot with fish © Chris Gomersall (rspb-images.com)
All other photos Marine Wildlife © Paul Kay

Cover design by:
Lynx Graphic Design (www.lynxgraphicdesign.co.uk)

FOREWORD

With the passage of the Marine (Scotland) Act 2010, Scotland has shown its desire to protect and enhance one of the most diverse ecosystems on the planet – our marine environment. Now we must seize the opportunity provided by this new legislation and achieve our shared vision for a clean, healthy, safe, productive and biologically diverse marine and coastal environment. With cross-sector support, this vision can become a reality, but only if we use the full range of measures now available to us. Of vital importance is the designation of a well-managed, ecologically coherent network of Marine Protected Areas (MPAs).

Scottish Environment LINK commissioned this scientific report to inform and shape our position on the management of nature conservation MPAs. 'Making the case for sound management of Marine Protected Areas' has been independently produced by the Scottish Association of Marine Science.

The report highlights that MPAs are not only important to protect our marine wildlife, but also vital for our economy and the fight against climate change. Crucially, it recognises that management decisions are just as important as the designation of sites in the creation of an ecologically coherent network that will help us achieve our shared vision for Scotland's marine environment. Development of conservation objectives and management plans will be vital steps in this process and provide an opportunity to radically change the face of marine nature conservation.

The report endorses some long-standing views, held by LINK and many others, on how MPA management practices can be carried out in Scotland to support a biologically diverse and productive marine environment. For example, whilst damaging activities must be managed, harmonious activities should be encouraged. If damaging activity continues to occur within a protected site, regulatory measures such as Marine Conservation Orders, will be required. Guidelines and codes of conduct for recreational and tourism activities should be promoted, while fisheries legislation and fisheries management plans such as those prepared by Inshore Fisheries Groups, must ensure conservation objectives for MPAs are met.

Other measures recommended in the report include Environmental Impact Assessments for commercial fisheries; buffer zones around fish farms; and the use of no-take zones. Crucially, as with the designation of sites, all management decisions must be based on the best available scientific knowledge.

Getting the right sites designated is central to the success of Scotland's new approach to marine conservation. However, for a real success story, we are dependent on how economic and social activities are managed in and around these areas in order to achieve conservation objectives. If we succeed at this, we will have made a huge step towards safeguarding marine biodiversity and recovering the health of our seas.

We hope the recommendations made in this report will provide a useful tool for decision makers and delivery bodies. We wish to encourage transparency and inclusivity in the development of MPAs with clear objectives and the use of an adaptive co-management approach. Ultimately, the success of an MPA is wholly reliant on political will to develop management plans, implement the necessary regulatory measures and invest in long-term monitoring and research programmes. The integration of competing industries will be challenging, but it must not be forgotten that healthy marine ecosystems underpin all goods and services provided by the sea. Making the correct management decisions now is vital to meet the long-term needs of people and nature.

Scottish Environment LINK's Marine Task Force

SCOTTISH
ASSOCIATION
for MARINE
SCIENCE

Making the case for the sound management of Marine Protected Areas

A Report to Scottish Environment LINK

Table of Contents

1 Executive Summary

The purpose of this scientific report is to inform the LINK position on the sound management of Nature Conservation Marine Protected Areas (NC-MPAs) following their designation under the Marine (Scotland) Act 2010. If well planned, appropriately resourced and properly managed, MPAs can play an important role in both nature conservation and the wider economy, benefiting marine industries as well as helping to mitigate the effects of climate change on marine ecosystems. The new Scottish legislation is based on the three pillar approach to marine conservation in Scotland, as elaborated in the draft Strategy for Marine Conservation in Scotland (Marine Scotland 2010). The three pillars are wider seas policies and measures, species conservation and site protection.

This report places an emphasis on site-based management measures and is limited to Nature Conservation MPAs for the protection of biodiversity and geodiversity. The Marine (Scotland) Act 2010 also includes provisions to designate Demonstration and Research MPAs and Historic MPAs. We support the concept of these MPAs, but detail on the management of such sites is beyond the scope and purpose of this work. For the purpose of this report, the term 'MPA' will be used to refer to Nature Conservation MPAs (NC-MPAs) unless otherwise stated.

It is essential that areas or species already designated some level of protection under other legislations, e.g. the EC Habitats/Birds Directive, SPA, SACs, SSSIs, are not and should not be precluded from inclusion in wider MPAs, e.g. seawards extensions to encompass critical habitats, for nationally important populations of marine species or habitats. This is especially important where existing sites/protective measures are not deemed to provide adequate protection for nationally important populations or habitats in a given region, e.g. where populations of species do not meet European thresholds.

The report recognises that it is critical that the management of MPAs protects identified features according to their ecological requirements and viability. Determining the 'ecological need' of habitats and species is scientifically complex and we strongly support the articulation of this in the evolving definition of 'ecological coherence', based on the 2007 OSPAR[1] definition which states that:

"An ecologically coherent network of MPAs:

i. *interacts and supports the wider environment;*
ii. *maintains the processes, functions, and structures of the intended protected features across their natural range;*
iii. *functions synergistically as a whole, such that the individual protected sites benefit from each other to achieve the two objectives above; and*
iv. *(additionally) may be designed to be resilient to changing conditions."*

This is discussed further in Section 3 in relation to priority marine features.

This report's focus on management does not mean that we consider that social and economic considerations are only relevant during the management of MPAs and not before. While a discussion of the identification and designation of MPAs is beyond the scope of this paper, we underscore the importance of considering ecological, social and economic factors at all stages of the MPA process. It is essential to 'take the community with us' to maximise the benefits of MPAs for ecosystems and society.

The report then considers seven examples of either ecologically meaningful habitats that protect one or more of the species listed in Annex 3 of the draft MPA guidelines, Marine Protected Areas in the Seas around Scotland (Marine Scotland 2010), or individual species. This approach takes into account ecological coherence, viability and function, rather than selecting features on an individual basis. The features are: tidally swept communities, biogenic reefs, seagrass beds, native oyster beds, burrowed deep muddy habitats, seamounts and mobile species. Mobile species are included as an example, because it is recognised that a coherent MPA network must include sites and critical habitats that are fundamental to the survival of species such as seabirds, cetaceans, pinnipeds, fish and invertebrates. The results are summarised in Table 1 and further information is contained in Appendix 2.

[1] http://www.ospar.org/documents/DBASE/Publications/p00319_OSPAR_MPA_status_report%202006.pdf

The final section of the report makes recommendations for the management of MPAs in Scotland.

Table 2 identifies management options for MPAs, showing the impacts of different sectors and how they can be managed by a mix of MPA ‘site’ instruments and ‘wider measures’ external to MPAs. This section highlights the benefits of joined-up thinking and the important role of Marine Spatial Planning in managing MPAs. It also makes general recommendations for MPA management (and implicitly design) and includes a section on adaptive management in the context of climate change.

Key recommendations include that MPA site selection, decision-making and management should be based on the best currently available scientific knowledge and investment must be made into integrated MPA research, including ecological, social and economic considerations. An adaptive (co-)management approach is essential, especially in the context of climate change as is the use of a range of policy instruments and regulatory levers. Where our understanding of habitat functional roles is rudimentary or there is a lack of data, precautionary management strategies are required. Furthermore, protected areas are only effective if they are monitored, and this allows for adaptive management of MPAs. Monitoring is challenging in regions far from shore, for example, deep-water and offshore seamounts.

It is recommended that opportunities for appropriate access to and/or compatible use of marine resources consistent with MPA management plans, conservation objectives and ecological coherence should be encouraged, using zoning and spatial planning measures.

MPA objectives must be clearly defined in a transparent and inclusive manner and it is essential to commit to a common understanding and interpretation of the significance of MPAs among stakeholders. Increasing public awareness about ecosystem functioning and the role of MPAs is also important, especially in the context of evolving environmental challenges such as climate change and associated ocean acidifcation.

Table 1. Summary table for pressures on Priority Marine Features & MPA management priorities.

Feature	Biotope / species	Conservation status	Pressures	Recovery potential	MPA management priorities
Tidally swept communities	Flame shell *Limaria hians*	UKBAP, SBL	Mobile fishing gear Coastal infrastructure Localised anchorages & moorings	No data	Spatial management of mobile gear, e.g. scallop dredging and trawling in MPAs, including closed areas Mapping of *L. hians* beds Reduce impacts of transboundary damaging activities outside MPAs Improve monitoring and conservation biology including recovery studies
	Horse mussel beds *Modiolus modiolus*	UKBAP, SBL, OSPAR, EU	Localised fishing Mobile fishing gear: dredging Coastal infrastructure Spoil and waste dumping Aquaculture	Sporadic and poor annual recruitment Long recovery time Long lived species	Restriction and management of activities not compatible to *Modiolus* conservation in MPAs. This may include closed areas. Buffer zones for infrastructure development to reduce sedimentation. Spatial planning of marine cage aquaculture to minimise impacts Reduce impacts of transboundary damaging activities outside MPAs Long term research into recovery & monitoring Linked MPA sites for improved recruitment
	Maerl beds	UKBAP, SBL, OSPAR, EU	Scallop dredging Commercial extraction Aquaculture nutrient pollution and smothering Coastal infrastructure Localised anchorages & moorings	Long lived species (some maerl beds 8000 years old) Low regenerative capacity – slow growth (1mm/year) High sensitivity to physical factors e.g. smothering	Activities not compatible to maerl conservation excluded from MPAs. This may include closed areas. Long term MPA planning and monitoring. Reduce impacts of transboundary damaging activities outside MPAs Representative MPAs of biotope across the UK and NE Atlantic Increase monitoring and disturbance / recovery studies of maerl biotope.

Feature	Biotope / species	Conservation status	Pressures	Recovery potential	MPA management priorities
Biogenic reefs	*Lophelia pertusa*	UKBAP, OSPAR, EU	Localised fishing Mobile gear: trawling Oil and gas extraction Deep-sea mining Pipeline and cable laying Climate change Ocean acidification	Extremely long recovery time Long lived species (100s years) Slow growing Low recruitment	Restriction and management of activities incompatible with *Lophelia* conservation in MPAs. This may include closed areas. Buffer zones for infrastructure development to reduce sedimentation and physical disturbance Networked MPA sites for improved recruitment Long term research into ecology, recovery & monitoring Adaptive management approach to climate change and ocean acidification Reduce impacts of transboundary damaging activities outside MPAs
	Serpulid reefs *Serpula vermicularis*	UKBAP, EU	Localised fishing Mobile gear: trawling and dredging Coastal infrastructure Aquaculture Chain and anchor damage from moorings Hand collection	High potential for recovery Episodic annual reproduction Life span 2-5 years	Restriction and management of activities incompatible with *Serpula* conservation in MPAs in particular fishing, anchorages and moorings. This may include closed areas. Buffer zones for infrastructure development to reduce sedimentation and physical disturbance Networked MPA sites for improved recruitment Long term research into recovery & monitoring Reduce impacts of transboundary damaging activities outside MPAs
	Horse mussel reefs *Modiolus modiolus*	UKBAP, SBL, OSPAR, EU	Localised fishing Mobile gear: dredging Predation Coastal infrastructure Spoil and waste dumping Aquaculture Chain and anchor damage from moorings Target fishery	Long recovery time Sporadic and poor annual recruitment Long lived spp.	Restriction and management of activities incompatible with *Modiolus* conservation in MPAs. This may include closed areas. Buffer zones for infrastructure development to reduce sedimentation. Spatial planning of marine cage aquaculture to minimise impacts Long term research into recovery & monitoring Networked MPA sites for improved recruitment Reduce impacts of transboundary damaging activities outside MPAs

Feature	Biotope / species	Conservation status	Pressures	Recovery potential	MPA management priorities
Biogenic reefs (cont.)	Common/Blue Mussel reefs *Mytilus edulis*	UKBAP, OSPAR	Localised fishing Mobile fishing gear: dredging Sedimentation and subsequent parasitic infection Aquaculture Pollution: hydrocarbons and TBT Storms Predation	High to intermediate recovery potential Poor annual recruitment Short lived	Restriction and management of activities incompatible with *Zostera* spp. conservation in MPAs. This may include closed areas. Buffer zones for infrastructure development to reduce sedimentation. Spatial planning of marine cage aquaculture to minimise impacts Long term research into recovery & monitoring Networked MPA sites for improved recruitment Reduce impacts of transboundary damaging activities outside MPAs
Seagrass beds	*Zostera* spp.	UKBAP, SBL, OSPAR, EU	Disease, grazing and storms Water pollution: nutrients, heavy metals from aquaculture and terrestrial runoff Physical disturbance: coastal infrastructure, mobile fishing gear anchorages.	Long recovery time (5-10 years). Sensitive to physical disturbance and smothering. High seed mortality	Restriction and management of activities incompatible with *Zostera* spp. conservation in MPAs. This may include closed areas. Ensure ecological requirements for *Zostera* spp. are met through MPA design Industrial activities within MPAs not detrimental to recovery. Minimising physical disturbance and sedimentation within and external to MPAs. Long term recovery of *Zostera* must link to long term MPA planning Increase active restoration e.g. transplantation Reduce impacts of transboundary damaging activities outside MPAs

Feature	Biotope / species	Conservation status	Pressures	Recovery potential	MPA management priorities
Native oyster beds	*Ostrea edulis*	UKBAP, SBL, OSPAR	Harvesting Water pollution Smothering from coastal infrastructure construction or towed gear Disease and parasites	Recovery likely to be slow due to variable recruitment and pressures from competitors, pests and disease. Requires hard substrate. Recovery of 10-25 years.	Spatial management of *O. edulis*. This may include closed areas. MPAs must contribute to restoration of *O.edulis* (OSPAR Criteria ii) over long time scales Creation of appropriate habitat features (e.g. hard substrate 'cultch') and linkage between sites 'corridors' for larval dispersal Direct prevention of overharvesting/illegal gathering Minimisation of physical disturbance and smothering in proximity to MPA Active monitoring of sites and removal of pests / invasive sp. MPA should drive public education about restoration Reduce impacts of transboundary damaging activities outside MPAs
Burrowed deep muddy habitats	Seapens, burrowing megafauna	UKBAP, OSPAR	Mobile gear: dredging and trawling Anchoring and mooring Smothering Organic enrichment	No data	Restriction and management of activities incompatible with seapen and burrowing megafaunal conservation in MPAs. This may include closed areas. Buffer zones for infrastructure development to reduce sedimentation. Spatial planning of marine cage aquaculture to minimise impacts Long term research into recovery & monitoring Reduce impacts of transboundary damaging activities outside MPAs

Feature	Biotope / species	Conservation status	Pressures	Recovery potential	MPA management priorities
Seamounts		UKBAP (*Lophelia* on seamounts), OSPAR, UNICPOLOS	Mobile gear: trawling Cable and pipeline laying Vessel anchoring Waste disposal CO_2 sequestration Climate change Ocean acidification Sampling activities	No data available but likely to be very slow recovery due to long-lived spp. present in communities and poor recruitment between widely dispersed seamount communities	Adoption of a precautionary management approach due to lack of data and adaptive approach to climate change and ocean acidification Restriction of activities incompatible with seamount conservation. This may include closed areas. Buffer zones for infrastructure development to reduce physical damage, disruption of water movement, sedimentation. Long term research into recovery & monitoring Networked MPA sites for improved recruitment Take into account role as critical habitat for many species, including mobile species, when determining conservation strategies Reduce impacts of transboundary damaging activities outside MPAs
Mobile species	Seabirds e.g. Black guillemot: *Cepphus grylle*	UKBAP, EU	Fishing By-catch Offshore renewable energy devices Pollution and contaminants CO_2 sequestration Climate change and ocean acidification impacts on prey distribution Marine (eco)tourism	Slow recovery *k*-selected spp. Long-lived Slow growing Low annual recruitment	Restriction of activities incompatible with seabird conservation. This may include closed areas. Protection of critical habitats and movement corridors Seaward extension of existing land-based site protection Adaptive management approach to climate change and ocean acidification Scientific research and monitoring Promotion and/or production of existing codes of conduct Reduce impacts of transboundary damaging activities outside MPAs

Feature	Biotope / species	Conservation status	Pressures	Recovery potential	MPA management priorities
Mobile species (cont.)	Cetaceans Various	UKBAP, EU, IUCN, CITES	Fishing By-catch Aquaculture Boat and propeller collision Offshore renewable energy devices Military activities Oil and gas exploitation Pollution and contaminants CO_2 sequestration Climate change and ocean acidification impacts on prey distribution Marine (eco)tourism	Slow recovery *k*-selected spp. Long-lived Slow growing Low recruitment Energy-expensive young	Restriction of activities incompatible with cetacean conservation. This may include closed areas. Protection of critical habitats and movement corridors Adaptive management approach to climate change and ocean acidification Scientific research and monitoring including public sighting initiatives Promotion and/or production of existing codes of conduct Reduce impacts of transboundary damaging activities outside MPAs
	Pinnipeds e.g. grey seal: *Halichoerus grypus* & common seal: *Phoca vitulina*	EU	Fishing By-catch Aquaculture Offshore renewable energy devices Military activities Oil and gas exploitation Pollution and contaminants Marine (eco)tourism	Slow recovery *k*-selected spp. Long-lived Slow growing Low recruitment Energy-expensive young	Restriction of activities incompatible with pinniped conservation. This may include closed areas. Protection of critical habitats and movement corridors Seaward extension of existing land-based site protection Scientific research and monitoring Promotion and/or production of existing codes of conduct Reduce impacts of transboundary damaging activities outside MPAs

Feature	Biotope / species	Conservation status	Pressures	Recovery potential	MPA management priorities
Mobile species (cont.)	Fish e.g. Common skate: *Raja batis* Basking shark: *Cetorhinus maximus*	UKBAP, WCA, CRoW, EU, IUCN, CITES, OSPAR	Fishing By-catch Boat and propeller collision Offshore renewable energy devices Pollution and contaminants CO_2 sequestration Climate change and ocean acidification impacts on prey distribution Marine (eco)tourism	Recovery dependent on spp. *k*-selected spp., e.g. Basking shark, recovery slow: Long-lived Slow growing Very low, sporadic recruitment Energy-expensive young	Restriction of activities incompatible with fish conservation. This may include closed areas. Vessel and speed restrictions Protection of critical habitats and movement corridors Adaptive management approach to climate change and ocean acidification Scientific research and monitoring including public sighting initiatives Promotion and/or production of existing codes of conduct
	Invertebrates e.g. European spiny lobster: *Palinurus elephas*	UKBAP	Fishing By-catch Pollution and contaminants Climate change and ocean acidification impacts on prey distribution	Insufficient data about longevity and fecundity but fecundity known to be lower for this sp. than other spiny lobster spp. rendering them more vulnerable to over-exploitation and impacts and slow to recover	Restriction of activities incompatible with invertebrate conservation. This may include closed areas. Protection of critical habitats and movement corridors Scientific research and monitoring

Table 2. Management options for MPAs

Activity	Pressure	Impact	Features	MPA management instrument	'Wider seas' instrument
Fisheries	Mobile gear: scallop dredging Mobile gear: trawling	Physical disturbance Smothering Direct mortality By-catch	Flame shell Horse mussel beds Maerl Seagrass Native Oyster Biogenic reefs Burrowed deep muddy habitats Seamounts Mobile spp.	• Marine (Scotland Act) s.85 marine conservation order. (spatial &/or temporal s.85c, speed restrictions s.86 (2)a) • Urgent orders s.88 • Assessment of impact s.91	• Including fisheries in EIA – Amendment to Schedule 2 of The Environmental Impact Assessment (Scotland) Regulations • Inshore fishery order: Inshore Fishing (Scotland) Act 1984 • Shellfish Management Order. The Sea Fisheries (Shellfish) Act 1967. • Including impact mitigation into IFG management plans. SEA of management plans • Social, economic and ecological objectives in MSP • VMS tracking • Offshore: enforcement under the Offshore Marine Conservation (Natural Habitats, &c.)(Amendment) Regulations 2007/2010; • Offshore: CFP technical conservation measures • Regulatory reform to CFP (Control Regulations) and Scottish Technical measures for protection of offshore Scottish MPAs. • Scientific monitoring of impacts and recovery including minimal damage measures. • Species protection pillar (e.g. NCA 2004) • Voluntary market initiatives e.g. ecolabelling
	Hand collection	Physical disturbance	Native oyster	s.85 marine conservation order	• Inshore fishery order: Inshore Fishing (Scotland) Act 1984
	Fixed gear (creels)	Physical disturbance	Muddy habitats / sea pens	s.85 marine conservation order	• Including fisheries in EIA & SEA • Inshore fishery order: Inshore Fishing (Scotland) Act 1984 • Including impact mitigation into IFG management plans • Scientific monitoring of impacts • Mutual development opportunities. • Voluntary market initiatives e.g. ecolabelling

Activity	Pressure	Impact	Features	MPA management instrument	'Wider seas' instrument
Aquaculture	Proximity of cages to features	Nutrient enrichment Smothering Dissolved oxygen Contamination	Tidally swept communities Biogenic reefs Burrowed deep muddy habitats Seagrass Burrowing deep mud Mobile species	s.85 marine conservation order (spatial)	• EIA (for new developments) • Spatial planning through regional MSP to avoid sensitive sites and areas. • Licensing instruments: local authority & Marine Scotland development and farm siting consents. Town and Country Planning Marine Fish Farming (Scotland) Order 2007 • Development of buffer zones. • Stricter discharge consents under Water Environment (Controlled Activities) (Scotland) Regulations (2005) if near priority features. • Scientific monitoring of impacts • Identification of new opportunities e.g. integrated developments, offshore sites.
Coastal infrastructure	Building fixed structures e.g. renewable devices, bridges, cables and pipelines	Physical disturbance Altered hydrology Turbidity	Tidally swept communities Biogenic reefs Burrowed deep muddy habitats Seagrass Seamounts Mobile species	s.85 marine conservation order	• EIA and SEA for new developments taking into account impact on features or occurring in proximity to MPAs. • MSP: national and regional planning and objectives. • Inclusion of MPA and MSP into the National Planning Framework(The Planning etc. (Scotland) Act 2006, Part 1 s.3A) • Strategic and local development planning in local authorities (part 2, The Planning etc. (Scotland) Act 2006) • Part II of the Food and Environment Protection Act *1985* (*FEPA*) • Crown Estate licence / lease • The Merchant Shipping Act and Merchant Shipping and Maritime Security Act 1997 (Ports near MPAs) • Licensing under s.36 The Electricity Act 1989 s.36 • Biodiversity Duty under NCA 2004
Recreation and marine tourism	Local anchorages and moorings Vessels traveling at speed	Physical disturbance Collisions	Biogenic reefs Seagrass Burrowed deep mud Mobile species	s.85 marine conservation order	• Crown Estate mooring license • Species pillar actions • Licensing through Marine (Scotland) Act 2010. • Regional MSP for marinas and moorings in proximity to MPAs. • Green-Blue Initiative • Wild Scotland and Best Practice Guidelines • Scottish Outdoor Access Code

Activity	Pressure	Impact	Features	MPA management instrument	'Wider seas' instrument
Land based run-off from agriculture, sewage	Water pollution: eutrophication, heavy metals		Biogenic reefs (coastal based) Seagrass Native Oyster	s.85 marine conservation order	• Water Environment and Water Services (Scotland) Act 2003 • The Water Environment (Controlled Activities) (Scotland) Regulations 2005 – license for point and diffuse pollution. • Linking to MPAs: The Water Environment (Register of Protected Areas) (Scotland) Regulations 2004 • Codes of conduct and guidance
Dumping	-	Smothering Pollution	Biogenic reefs Seagrass Native Oyster Burrowing deep mud	s.85 marine conservation order	• Part II of the Food and Environment Protection Act *1985* (*FEPA*) • Marine spatial planning and licensing under the Marine (Scotland) Act 2010
Dredging (sediment)		Turbidity	Biogenic reefs Seagrass Native Oyster Burrowing deep mud		• Part II of the Food and Environment Protection Act *1985* (*FEPA*) • Marine spatial planning and licensing under the Marine (Scotland) Act 2010
Shipping and marine scientific research			Seamounts Mobile species		• The Merchant Shipping Act and Merchant Shipping and Maritime Security Act 1997 • Marine spatial planning • IMO Particularly Sensitive Sea Areas • The Offshore Marine Conservation (Natural Habitats, & c.) Regulations 2007 • Marine Environment High Risk Areas (MEHRAs; UK instrument under MARPOL)

2 Management of Marine Protected Areas at the social-ecological interface

2.1 Introduction

> *"…if the object of development is to provide for social and economic welfare, the object of conservation is to ensure the Earth's capacity to sustain development and to support all life…. Development and conservation are equally necessary for our survival and for the discharge of our responsibilities as trustees of natural resources for the generations to come."* (IUCN et al. 1980)

> *"MPAs are profoundly affected by the larger ecological, social, economic, and political context of the coastal/ocean areas of which they are a part."* (Cicin-Sain & Belfiore 2005).

MPAs have successfully been used as a management measure to mitigate human-induced impacts on marine ecosystems (Pollnac et al. 2010), and it is this contribution of reducing negative impacts on marine ecosystems that also portrays them as an important component of an ecosystem-based management approach (Halpern 2003, Halpern et al. 2010). Evidence exists that MPAs, and particularly no-take areas or marine reserves, can help restore ecosystem structure and function and protect marine biodiversity and associated ecosystem services (cf. National Research Council 2001, Palumbi 2002, Roberts et al. 2003, Sobel & Craig 2004, Lester et al. 2009). MPAs can be defined as:

> *"A geographically defined area, which is designated or regulated and managed to achieve specific conservation objectives".* – Article II, Convention on Biological Diversity (1992)

> *"Marine protected area" means an area within the maritime area for which protective, conservation, restorative or precautionary measures, consistent with international law have been instituted for the purpose of protecting and conserving species, habitats, ecosystems or ecological processes of the marine environment.*" (OSPAR Commission 2003).

It is crucial to understand that MPAs exist at the interface of complex social and ecological linkages (Pollnac et al. 2010). While social and economic activities occur within the limits of natural systems, it is important to acknowledge that the ecosystem consists of both humans and the environment with interactions and feedbacks between the two (Brennan et al. 2010). Social and cultural, and political conditions shape the ways in which humans use and manage resources, including the identification, designation, and management of protected areas (Bruner et al. 2001). For example, while it is necessary for marine protected areas to have a solid foundation in ecology (Roberts et al. 2003) their success hinges upon user compliance (National Research Council 2001) which in turn depends on factors including the MPA features, enforcement capabilities, community monitoring, the level of adaptive management, consultation, and training (Pollnac et al. 2010). If MPAs are established without stakeholders as a part of the process, it is most likely that conservation objectives will not be achieved because those who perceive the process as unfair will have an incentive to undermine the system (Hanna 1996, Pálsson & Helgason 1996).

This paper focuses on the management of MPAs and not on the prior stages of identification and designation. However we underscore the importance of considering ecological, social and economic factors at all stages of the MPA process by highlighting a Key Lesson Learnt by the IUCN (Pálsson & Helgason 1996, Kelleher 1999) as follows:

> *"Socio-economic considerations usually determine the success or failure of MPAs. In addition to biophysical factors, these considerations should be addressed from the outset in identifying sites for MPAs, and in selecting and managing them"* (Kelleher 1999).

Nevertheless, where science has identified a site as being of national importance beyond reasonable scientific doubt and worthy of protection within a nature conservation MPA (NC-MPA) and/or as contributing to an ecologically coherent MPA network, social and economic considerations should not over-ride site selection. Indeed, the Cabinet Secretary for the Environment has said that: *"…science remains the primary consideration when identifying MPAs for inclusion in the network."*[2] Stakeholder consensus was also reached in Scotland that sites should be designated according to science (e.g. Advisory Groups on Marine and Coastal Strategy (AGMACS)[3] and the Sustainable Seas Task Force.

[2]http://www.scottish.parliament.uk/s3/committees/rae/bills/Marine%20bill/documents/20100201CabSecMPANetwork-formatted.pdf

[3] http://www.scotland.gov.uk/Topics/marine/seamanagement/marineact/16440

2.2 Benefits of MPAs

The complexity of MPAs is evident from a recent study (Angulo-Valdés & Hatcher 2010) which identifies a total of 99 benefits of MPAs within two main classes: those accruing to humans and those accruing to nature. These are summarized in Table 3 and detailed in Appendix 1. Within the human benefits category, a further division is made between direct and indirect benefits. Direct benefits are provided mainly by ecosystem goods, while indirect benefits are generally derived from ecosystem services. Five main categories of benefits to humans and four main categories of benefits to nature are identified. Most of the benefits included within these categories present indirect but vital links to humans (Angulo-Valdés & Hatcher 2010) (see Appendix 1). Furthermore, because a 'value' is an inherently human notion, most of the MPA benefits are anthropocentric by their very nature because, generally speaking, "MPAs are human impositions on nature and society" (Oracion et al. 2005).

Table 3. Categories of benefits of MPAs (adapted from Angulo-Valdés & Hatcher (2010)).

Benefits of MPAs to humans	Benefits of MPAs to nature
Fishery	Process
Non-fishery	Ecosystem
Management	Population
Education/research	Species
Cultural	

The benefits of multiple-use MPAs are not yet fully understood, but the fisheries, species and population benefits of no-take MPAs (marine reserves) are well–documented. One recent global review carried out by the Partnership for Interdisciplinary Studies of Coastal Oceans (2007)[4] identified that: "*fishes, invertebrates, and seaweeds had the following average increases inside marine reserves: 1. Biomass, or the mass of animals and plants, increased an average of 446%. 2. Density, or the number of plants or animals in a given area, increased an average of 166%. 3. Body size of animals increased an average of 28%. 4. Species diversity, or the number of species, increased an average of 21% in the sample area.*" In time these organisms 'spillover' into adjacent areas enhancing ecological and economic benefits (Gell & Roberts 2003). Moreover, an ecologically viable marine

[4] http://www.piscoweb.org/

reserve with high densities of marine organisms can attract tourists (Roberts & Hawkins 2000).

The social and economic benefits of well managed MPAs also extend beyond the direct use of marine ecosystems such as fisheries and tourism. They encompass a wide range of indirect benefits including maintenance of marine ecosystem services (such as coastal protection, storm control, carbon sequestration and the provision of breeding grounds and habitats for different species), the potential benefits associated with future possible uses of marine ecosystems (such as pharmaceutical and industrial applications) and cultural heritage, aesthetic and natural benefits (Salm et al. 2000). Of importance to Scotland is their potential role in enhancing the overall image and 'brand' of a nation; being a wild, natural tourist destination depends upon functional ecosystems not just scenery.

However, debate still exists about the overall benefits of MPAs. MPAs or reserves which prohibit extractive activities have successfully been used as a management measure to mitigate impacts (Pollnac et al. 2010). However, MPAs can produce highly variable ecological effects (Lester et al. 2009) and only a small proportion of this variability has been explained by species and/or area characteristics (Halpern et al. 2010). Therefore, it has been suggested that the context of the MPA, including activities in the waters that surround it, may play an important role in its effectiveness (Halpern et al. 2010). This reiterates 1) the importance of social and economic considerations in determining the success or failure of MPAs and 2) that the 3 pillar approach is critical in MPA management.

It is evident that designating significant areas of coastal regions as MPAs will alter both the kind of benefits (or ecosystem goods and services) provided by the marine environment and the distribution of these benefits among different groups of individuals. National governments should be aware of this fact in order to properly manage and maximize these benefits in the interests of their citizens (Angulo-Valdés & Hatcher 2010).

2.3 Linking benefits to MPA objectives

Nature Conservation MPAs (NC-MPA) need to define objectives under the Marine (Scotland) Act (detailed in Section 4 of this report.) However, the clarity of these objectives can be muddied by an inappropriate portrayal of the benefits that may flow from NC- MPAs. As one fisherman succinctly put it:

> "*I think that having primary biodiversity objectives would be the most practical, clear and honest approach. Whilst they might have coincidental fisheries benefits, they should not be sold on this basis as the potential benefits are too uncertain, as fishermen know well, so whilst win–win is a nice ideal, I do not think it is appropriate in reality*" (Jones 2008).

The need for honesty is highlighted further by the fact that 20% of fishermen interviewed stated that no-take MPAs (or marine reserves) should be primarily focused on biodiversity conservation objectives and that MPA advocates should not try to sell them on the basis of their potential fisheries benefits (Jones 2008).[5] Fisheries benefits are a possibility not a certainty and would be more clearly articulated as a part of Research and Demonstration MPAs (s71 of the Act).

Given that the primary purpose of a NC-MPA is nature conservation (s68(1) Marine (Scotland) Act), being honest about the consequences of its designation is more likely to avoid polarisation of a community. Establishing clear objectives is critical, builds trust, and allows for appropriate assessment of an MPA's success (Angulo-Valdés & Hatcher 2010). Clearly stated conservation objectives from the outset will facilitate public acceptance of MPAs (Angulo-Valdés & Hatcher 2010) and enable provisions for compensating those displaced from an MPA through appropriate mechanisms (Carter 2003).

Regardless of how objectives are set up, more often than not MPA management creates 'winners' and 'losers' (Oracion et al. 2005). If the process works smoothly, those affected by the MPA will accept whatever the outcome because of their continued confidence in the decision-making system (Oracion et al. 2005). However, if management decisions are perceived as unfair, this creates incentives to undermine

[5] The research focuses on the fishing industry in SW England.

the established management system (Hanna 1996, Pálsson & Helgason 1996) and can lead to undermining of MPA management (Oracion et al. 2005).

3 Priority Marine Features

A list of Priority Marine Features (PMFs) has been produced by Scottish Natural Heritage (SNH)[6] and a subset of this is included within Annex 3 of the Draft Guidelines on the selection of MPAs and development of the MPA network issued by Marine Scotland in March 2010. Seven examples of either ecologically meaningful habitats that protect one or more of the species listed or individual species were selected for this report. Mobile species were included because a coherent MPA network must include sites and critical habitats that are fundamental to the survival of mobile species. This approach takes into account ecological coherence, viability and function, rather than selecting features on an individual basis.

In this Section of the report, each group of PMFs is described (see also Appendix 2), the pressures on them considered and MPA management priorities recommended. The results are summarised in Table 1. It is important to note here that high biodiversity does not have to be a feature of all ecologically important areas. In some instances, a case may be made for protecting one or few species within an MPA that forms a crucial part of a wider, high diversity, heterogeneous and ecologically coherent MPA network.

The priority marine features considered in this report are:

1. Tidally swept communities
2. Biogenic reefs
3. Seagrass beds
4. Native oyster beds
5. Burrowed deep muddy habitats
6. Seamounts
7. Mobile species

A full description of each can be found in Appendix 2.

[6] http://www.snh.gov.uk/protecting-scotlands-nature/safeguarding-biodiversity/priority-marine-features/priority-marine-features/

3.1 Tidally swept communities

3.1.1 Description of tidally swept communities

Annex 3 of the Draft Guidelines mentioned above includes a number of habitats and biotopes that are found in tidally swept environments, and to maintain ecological coherence, these habitats have been grouped together in this report under this collective heading. These would include:

File or flame shell (*Limaria hians*) beds, which have the JNCC marine habitat code SS.SMx.IMx.Lim,[7] and are listed as a Priority Habitat in the UK Biodiversity Action Plan and the Scottish Biodiversity List (Hughes & Nickell 2009); Loch Sunart is an area where this habitat has been designated as an SAC in part because of these reef-forming beds.[8]

Horse mussel (*Modiolus modiolus)* beds (see also Section 3.2 on Biogenic reefs) which are listed as two separate habitats by the JNCC: SS.SBR.SMus.ModCvar,[9] with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tideswept very sheltered circalittoral mixed substrata, and SS.SBR.SMus.ModT, with hydroids and red seaweeds on tide-swept circalittoral mixed substrata.[10] They are listed as a Priority Habitat in the UK Biodiversity Action Plan,[11] and on the OSPAR List of Threatened &/or Declining Species and Habitats.[12] *Modiolus modiolus* beds exist in SACs such as Lochs Duich, Long and Ailsh, and Loch Creran SAC, the tidal Creagan Narrows (Moore et al. 2006), and are very numerous in Shetland and in the tidal narrows of Lochs Leven and Eil (Howson et al. 1994).

Maerl (SS.SMp.Mrl) beds which in this environment can consist of *Lithothamnion glaciale* in shallow, brackish water (SS.SMp.Mrl.Lgla),[13] *Lithothamnion corallioides* on muddy gravel (SS.SMp.Mrl.Lcor),[14] and *Phymatolithon calcareum* in clean gravel

---

[7] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001565
[8] http://www.jncc.gov.uk/ProtectedSites/SACselection/sac.asp?EUcode=UK0019803
[9] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000641
[10] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000657
[11] http://www.ukbap.org.uk/ukplans.aspx?id=37
[12] http://www.ospar.org/content/content.asp?menu=00120000000132_000000_000000
[13] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000696
[14] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000710

or coarse sand (SS.SMp.Mrl.Pcal).[15] The high biodiversity associated with maerl beds has led to them being classed as a Priority Habitat in the UK Biodiversity Action Plan[16] and the Scottish Biodiversity List. They are also listed on the OSPAR List of Threatened &/or Declining Species and Habitats (Hall-Spencer et al. 2010).

Tidal rapid habitats are listed as a Priority Habitat in the UK Biodiversity Action Plan.[17] While the JNCC Marine Nature Conservation Review[18] considers these environments to be < 5 m deep, this habitat is given a much broader depth range in the BAP, and there is no restrictive depth maximum.

3.1.2 Pressures on tidally swept communities

3.1.2.1 *Limaria hians*

There have been observed declines in *L. hians* where a reef complex has been destroyed. Hall-Spencer & Moore (2000a) note that despite the limited information on the species, it has disappeared from several areas where it was formerly common, including Skelmorlie Bank, Ayrshire, and Stravanan Bay, Isle of Bute, and the Clyde Sea (Hughes & Nickell 2009). The key pressures on this feature are:

- Mobile fishing gear, particularly scallop dredging (Hall-Spencer & Moore 2000a)
- Aquaculture: The literature has identified impacts on *L. hians in* Ireland. Minchin et al. (1987) showed that antifouling compounds (TBT) on salmon farming cages led to declines in spat settlement of *L. hians*. Beds that were close to cages were reduced to 2% of their previous extent. The use of TBT as an antifouling agent for fish farm cages was banned in 1987 by the U.K. government but anti-foulant clean-up strategies are necessary to eliminate residual, long-term effects, e.g. from flaked paints in sediments. Other anti-fouling agents, e.g. copper-based, still in use can have a detrimental effect on marine life.
- It is possible, but not covered in the literature, that damage to *L. hians* could come from the development of fixed structures and coastal works e.g.

[15] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000734
[16] http://www.ukbap.org.uk/UKPlans.aspx?ID=40
[17] http://www.ukbap.org.uk/UKPlans.aspx?ID=39
[18] http://www.jncc.gov.uk/ukbap/BAPHabitats55_Tide-swept Channels.doc

renewable energy devices, dredging, and coastal infrastructure including bridges, pontoons and moorings.

- Localised damage may occur from anchorages for recreational sailing.

3.1.2.2 *Modiolus modiolus*

The key pressures on this feature are:

- Small local scale fisheries exist for *Modiolus modiolus* in Scotland (Holt et al. 1998). Direct collection and fishing may have potential to be damaging to *Modiolus* beds.
- *Modiolus* are susceptible to direct impact from scallop dredging and trawling as described in Magorrian et al. (1995) and Holt et al. (1998). There is evidence that dredging around the margins of *Modiolus* beds has reduced aggregations to clumps rather than dense reefs. However, older and larger aggregates may form a barrier to dredging due to the hard substrate and reefs up to 1 m high (Holt et al. 1998).
- *Modiolus* are susceptible to physical disturbance from coastal infrastructure development, aggregate extraction, cable laying, and dumping.[19] Contaminants have been found in aggregations near disposal areas but the effects on *Modiolus* ecology are unknown.[20]
- Marine cage aquaculture has the potential to impact upon *Modiolus* beds through waste deposition but currently the evidence for direct impacts is minimal (Holt et al. 1998). However, as for *L. hians* above, antifouling compounds may affect *Modiolus* recruitment.[21]

3.1.2.3 Maerl beds

The key pressures on this feature are:

- MarLIN classify maerl[22] as ‘very sensitive’ to: substratum loss, smothering, increase in suspended sediment, desiccation and increase in emergence regime.

---

[19] http://www.ukbap.org.uk/ukplans.aspx?id=37
[20] Ibid.
[21] http://www.marlin.ac.uk/speciessensitivity.php?speciesID=3817
[22] http://www.marlin.ac.uk/speciessensitivity.php?speciesID=4121

- Maerl has been extracted in Europe for hundreds of years (Birkett et al. 1998). Commercial extraction occurs for food additives, filtration, pharmaceutical and cosmetic industry applications. In the Fal Estuary a licence to dredge 30,000 tonnes per year was given in 1978. Experimental dredging has been undertaken in Wyre Sound in Orkney.[23]
- Scallop dredging is a serious threat to populations of maerl in the UK and Europe (Birkett et al. 1998, Hall-Spencer & Moore 2000b, Barbera et al. 2003). Repeated dredging can lead to loss of structural complexity, reductions in biodiversity and long-term degradation of the habitat (Hughes & Nickell 2009).
- Smothering by marine cage aquaculture is likely to lead to degraded habitat. In a study by Hall-Spencer et al. (2006), smothering was associated with reductions in live maerl cover. Smothering can also occur from dredging or construction activities e.g. renewable energy infrastructure.
- Anchoring and moorings could cause significant structural damage to maerl.[24]
- Maerl is highly susceptible to physical disturbance from coastal infrastructure development.

3.1.3 Management options for tidally swept communities

Under the OSPAR classification (Hall-Spencer et al. 2010), maerl is classified as "moderately to highly sensitive to different threats", *M. modiolus* is "very sensitive", while *L. hians* does not have an individual classification and is included in the maerl designation. Slow growth, long life and poor recruitment all combine to make these species vulnerable to disturbance and any recovery problematic. Management options for maerl would include, where extraction occurs, a recognition that existing beds must remain; any marine planning for aquaculture or any other organic enrichment is avoided in important maerl areas; any construction takes maerl conservation into account; and that fishing does not affect designated maerl sites. These management options would apply equally to *L. hians*. The management of *M. modiolus* beds primarily involve the control of fishing, both dredging and bottom trawling. Thus for

[23] http://www.snh.gov.uk/about-scotlands-nature/species/algae/marine-algae/maerl/
[24] Ibid.

tidally swept habitats including maerl, *M. modiolus* and *L. hians* a combination of the above management strategies would need to apply.

3.2 Biogenic reefs

3.2.1 Description of biogenic reefs

The most important biogenic reef forming species in Scottish waters are the cold-water coral, *Lophelia pertusa*, the serpulid worm (*Serpula vermicularis*), horse mussels (*Modiolus modiolus*) and the common or blue mussel (*Mytilus edulis*).

Lophelia pertusa is the commonest reef-building cold-water coral; JNCC habitat code SS.SBR.Crl.Lop[25], classed as a Priority Habitat in the UK Biodiversity Action Plan[26] and listed on the OSPAR List of Threatened &/or Declining Species and Habitats (Hall-Spencer & Stehfest 2009). There are many reefs along the continental shelf and offshore banks such as Rockall, the Porcupine Seabight, a newly mapped inshore Mingulay reef complex in the Sea of Hebrides and the Darwin Mounds (Roberts et al. 2009b). *Lophelia pertusa* also grows on the legs of some North Sea oil rigs (cf. Roberts 2002b, Gass & Roberts 2006)**.**

Serpulid reefs are formed by the calcareous tubes of the worm, ***Serpula vermicularis***, JNCC habitat code SS.SBR.PoR.Ser.[27] They are classed as a Priority Habitat in the UK Biodiversity Action Plan.[28] In the UK the only known living serpulid reefs are found in Lochs Creran (Poloczanska et al. 2004) and Teacuis, Scotland (Dodd et al. 2009). Serpulid reef remains were identified in the Linne Mhuirich arm of Loch Sween. These are thought to have died out some time between 1982 and the mid-1990s (Hughes & Nickell 2009). The Loch Creran reefs are thought to be the best developed of their kind in the world and they are currently recognised under the EC Habitats Directive as a Special Area of Conservation (SAC).[29]

[25] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000457
[26] http://www.ukbap.org.uk/ukplans.aspx?id=45
[27] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000645
[28] http://www.ukbap.org.uk/ukplans.aspx?id=43
[29] http://www.jncc.gov.uk/ProtectedSites/SACselection/sac.asp?EUCode=UK0030190

Horse mussel (*Modiolus modiolus*) reefs are listed as two separate habitats by the JNCC: SS.SBR.SMus.ModCvar[30] and SS.SBR.SMus.ModT (see Section 3.1.1 on Tidally swept communities).[31] The reefs are more complex than horse mussel beds. They have been identified in Scottish SACs such as Lochs Duich, Long and Alsh, as tidal communities in Loch Creran SAC, the tidal Creagan Narrows (Moore et al. 2006), are very numerous in Shetland and in the tidal narrows of Lochs Leven and Eil (Howson et al. 1994).

Common or Blue Mussel (*Mytilus edulis*) reefs are JNCC habitat listed as a littoral biogenic reefs: LS.LBR,[32] as important components of a number of Priority Habitats in the UK Biodiversity Action Plan,[33] and listed on the OSPAR List of Threatened &/or Declining Species and Habitats (OSPAR Commission 2008). The best examples are found in large, shallow inlets and bays, especially estuarine areas, where there are mixed, firm sediments and string currents.

Biogenic reefs have important effects on their physical environment, as they:

- Stabilise substrates;
- Provide hard substrate for attachment of sessile organisms;
- Provide habitat heterogeneity (i.e. crevices, surfaces) for colonisation;
- Provide food sources for other organisms (e.g. faeces, pseudofaeces, sediments and direct consumption of the reef-forming organism by birds and benthic predators); additionally
- Some species, e.g. *Mytilus edulis*, are also important as a fishery;
- Concentrate biodiversity in 'hotspots'.

3.2.2 Pressures on biogenic reefs

By their nature, biogenic reefs are most susceptible to strong physical disturbances and hence fishing is the most damaging activity in a variety of biogenic reef types. It is now well established that trawling and dredging can damage biogenic reefs, seabed communities and emergent epifauna (Watling & Norse 1998, Auster & Langton 1999,

[30] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000641
[31] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000657
[32] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000198
[33] http://www.ukbap.org.uk

Kaiser et al. 2006). They are also biodiversity hotspots thus damaging them often disrupts entire communities (Auster 2005, Roberts et al. 2009b).

Overall threats to biogenic reefs include:

- Mobile fishing gears such as trawls and dredges
- Creels and lobster pots deployed on top of the reefs
- The deployment and lifting of anchors
- Chains and ropes dragging around (permanent) moorings
- Disruption of water movement, e.g. barrier walls or causeways, which affects the flow of water-bearing food over the reef
- Pollution
- Diver damage due to fin or hand contact with the reef, sediment resuspension, collection
- Aquaculture – localised deoxygenation and death of benthos (Holt et al. 1998)
- Oil drilling, pipeline and cable laying
- Construction projects/coastal developments, e.g. piers, slipways, marinas, harbours, rigs, renewable devices

3.2.2.1 *Lophelia pertusa*

Fishing has a significant impact on deep-water coral populations worldwide. Between 30-50% of *Lophelia* reefs off Norway have been impacted or destroyed by trawling (Fosså et al. 2002) and in heavily fished areas of the Tasman Sea Rise 95-98% of coral cover has been lost, providing little hope of a significant recovery. In Scotland, prior to the trawling closures established in 2004, trawl marks were identified across the Darwin Mounds (Wheeler et al. 2004). In addition, (Roberts et al. 2009a) reported acoustic evidence of trawl marks and visual records of anthropogenic waste at Mingulay. Moreover, target fishing, by-catch of fish and corals and habitat destruction may indirectly disrupt nursery grounds and remove shelter for many fish species, reducing the recruitment of new individuals thus reducing fish stocks further.

Based on current knowledge of recruitment, growth rates and age structure, recovery rates are extremely slow; recovery of colonies and thickets impacted by fishing gears may take hundreds of years (Auster 2005).

The destructive damage is not restricted to fishing. Oil and gas companies are being granted permission to prospect for oil and gas in deeper waters and deep-sea mining is becoming a commercial reality. In many parts of the world individual oil companies and the countries that license oil exploration follow tightly controlled procedures to limit environmental impact. Generally speaking seabed impacts are confined to a small area. However, if poorly regulated these activities may damage the reef by unleashing pollutants, physically damaging the reef or releasing clouds of sediments/drill cuttings, smothering the reef and its inhabitants (reviewed by Rogers 1999).

Climate change may lead to increased water temperatures, the increased frequency and ferocity of storm events, increases in the amount of freshwater released into the sea and increased sea-levels. Projected increases in atmospheric CO_2 show a series of potential scenarios based on current and predicted hydrocarbon usage. It is not yet understood how cold-water coral ecosystems would be effected by climate change but Roberts et al. (2009b) summarise the potential impacts as being: (1) restricted bathymetric or biogeographic ranges due to increases in sea-surface temperatures; (2) altered calcification rates, reef growth and recovery due to increased CO_2, reduced alkalinity and calcium carbonate saturation, and disrupted large scale oceanographic circulation patterns; 3) direct effects on seawater chemistry resulting in a drop in calcium carbonate saturation of surface seawater by about 30%; 4) CO_2-related changes in seawater chemistry could cause the depth below which coral skeletons dissolve (the aragonite saturation horizon) to become shallower by several hundred meters (Roberts et al. 2009b). A significant drop in calcification rate may have significant impacts on the growth and recovery of any reef structure built from calcium carbonate (Roberts et al. 2009b).

3.2.2.2 *Serpula vermicularis*

Serpula vermicularis is moderately tolerant of reductions in salinity and very fragile (Holt et al. 1998). Serpulid reefs in Loch Creran are protected from fishing by virtue of their topography and the SAC designation. However, they are extremely susceptible to damage from moorings and anchorages, and physical removal e.g. by divers. Historically, de-alginated seaweed residues from an alginate factory located on the shores of Loch Creran at Barcaldine caused widespread losses. Production ceased in 1996 but organic material still coats the seabed, giving rise to an extensive mat of sulphur reducing bacteria, *Beggiatoa* spp., and eliminating reefs for approximately 1 km (Moore et al. 2006). These impacts also highlight the potential for reef damage from other organic pollutants, e.g. fish farm residues.

3.2.2.3 *Modiolus modiolus*

Modiolus modiolus reefs appear to have a low sensitivity to natural threats (Holt et al. 1998). Infaunal beds are at a greater risk of predation but the accessible byssus threads on semi-infaunal beds in Scottish waters provide important shelter for young *M. modiolus* (Holt et al. 1998). The fragility of the reefs probably also varies with the degree to which they are infaunal (Holt et al. 1998). There are small-scale *Modiolus* fisheries in Scotland for human consumption and fishing bait (Holt et al. 1998) which have the potential to be damaging. However, *Modiolus* reefs have suffered widespread and long lasting damage from bottom fishing activities; scallop and queen scallop dredging and trawling are well known to cause dramatic decreases in the density and extent of horse mussel beds (Jones 1951, Magorrian & Service 1998, Roberts et al. 2004). Fishing with pots can also be damaging (Holt et al. 1998) and there is evidence that damage to the *Modiolous* beds in the Lochs Duich, Long and Alsh SAC was a direct result of gathering and harvesting by divers and indirectly via the collection of intertidal seaweeds and shellfish leading to reef habitat deterioration (Scottish Natural Heritage 2006). Recovery is impossible while fishing activities continue. In the absence of fishing, recovery depends on larval supply and the quality of the remaining habitat. Recovery would likely be slow from even small-scale *Modiolus* fisheries, since *M. modiolus* is a long-lived species (up to 50 years old) and the reef communities are commonly >25 years old and *M. modiolus* individuals do not reach sexual maturity until 3-6 years old (Anwar et al. 1990). Furthermore, their larvae spend a long time in the plankton thus recruitment is naturally low and sporadic.

3.2.2.4 *Mytilus edulis*

Mytilus edulis reefs are generally resilient to natural disturbances and have a strong ability to regenerate. The reefs are more vulnerable to physical disturbance as they get thicker and accumulate more mussel mud. Beds of a single year class are often poorly attached to the substratum and particularly susceptible (Holt et al. 1998). Reefs in less sheltered areas are sometimes removed by storms. Predation can also threaten reefs: the common starfish, *Asterias rubens,* has been reported to eradicate beds (Seed 1993) and bird predation is extremely important. Winter temperatures (Beukema 1992) and phytoplankton blooms (Holt et al. 1998) can also influence natural mortality.

Fishing is the most damaging anthropogenic activity threatening *M. edulis* reefs. *Mytilus edulis* is in itself an important fishery but one vulnerable to overexploitation, particularly when combined with poor recruitment. Harvesting by hand can maintain biodiversity and natural populations can recover if fisheries are managed correctly. Mobile fishing gears can cause direct widespread, long lasting damage and indirectly increased sediment levels as the results of dredging activities have been shown to result in enhanced infestations of the shell-weakening parasite, *Polydora ciliate*, with associated loss of condition and increased threat of predation (Ambariyanto & Seed 1991). *Mytilus edulis* has also been shown to be sensitive to some pollutants, including diesel (Bokn et al. 2009), sunflower oil (Mudge et al. 1993) and Tributyltin (TBT) (Widdows et al. 1987), and is known to bioaccumulate a wider variety of contaminants (summarised in Holt et al. 1998).

3.2.3 Management options for biogenic reefs

Currently, no national legislation exists protecting *Lophelia pertusa* reefs or cold-water coral colonies in general, although they do feature in the non-statutory UK Biodiversity Action Plan,[34] which recommends conservation actions including research on their distribution in UK waters and designation of MPAs. Since Greenpeace successfully lobbied the English High Court to extend the EU Habitats Directive to the 200 nm limit of the Exclusive Economic Zone in 1999, several draft SACs have been suggested by JNCC. The Mingulay reef complex and the Darwin Mounds are candidate SACs, along with four others including the Wyville-Thomson

[34] http://www.ukbap.org.uk/ukplans.aspx?id=45

Ridge (De Santo & Jones 2007). The fact that Mingulay lies within Scottish territorial waters has major implications: firstly, the reefs occur at shallow depths (120-190 m; (Roberts et al. 2009a) rendering them even more vulnerable to inshore fishing, aquaculture and pollution than offshore reefs; secondly, they fall exclusively within Scottish jurisdiction, the Marine Scotland Act and the Scottish biodiversity legislation (see Section 4.3 and Appendix 2), thus more management instruments are available (see Table 5) thus bold management decision to control impacts are possible. Bottom trawling, or fishing using gear which may contact the bottom, has been prohibited within an area of approximately 1,300 km^2 of the Darwin Mounds, northwest Scotland, since August 2004. Measures such as this should be extended to other reefs.

To date, many of the banks and shelves of Rockall remain overlooked, unprotected and poorly mapped. Recent activities such as the Strategic Environmental Assessment[35] initiative will generate new information based on new multibeam sonar surveys and photographic surveys, which may be used in conservation efforts (Roberts et al. 2009b).[36] Overall, due to our rudimentary understanding of the functional role of deep-water corals, precautionary management strategies are required.

The serpulid and *Modiolus* reefs are currently offered a degree of protection: Loch Creran has been designated as an SAC under the Habitats Directive (European Council Directive 92/43/EEC on the Conservation of Natural Habitats and of the Wild Fauna and Flora) for biogenic reefs of *Serpula vermicularis* and *Modiolus modiolus* (see Section 3.1.2.2 for *Modiolus* protection). Serpulid reefs are also listed as a priority habitat under the UK Biodiversity Action Plan (UK BAP).[37] The management of *M. modiolus* reefs primarily involves the control of fishing, both dredging and bottom trawling. Since physical disturbance from anchorages and moorings significantly impact biogenic reefs in shallow waters, Scottish Natural Heritage (SNH)[38] also suggest that moorings be restricted to areas with a seabed depth greater than 15 m, and the length of riser chain be limited to reduce movement around the anchor point. The serpulid reefs in Loch Teacuis are not currently listed as features,

[35] http://www.sea-info.net/
[36] http://www.lophelia.org/
[37] http://www.ukbap.org.uk/ukplans.aspx?id=43
[38] http://www.snh.gov.uk/about-scotlands-nature/species/invertebrates/marine-invertebrates/serpulid-reefs/

even though they are within the boundary of the Loch Sunart SAC, thus the control of fishing, anchorages and moorings in particular, is essential for these reefs.

3.3 Seagrass beds

3.3.1 Description of seagrass beds

Seagrasses, flowering marine plants, occur around the UK in beds in the intertidal or shallow subtidal. There are two main species involved, *Zostera noltii* and *Zostera marina,* which may be considered sometimes as separate species with *Zostera angustifolia. Zostera noltii* beds in littoral muddy sand (LS.LMp.LSgr.Znol)[39] and *Zostera marina/angustifolia* beds on lower shore or infralittoral clean or muddy sand (SS.SMp.SSgr.Zmar)[40] are the two main seagrass biotopes identified by the JNCC. Seagrass beds are a Priority Habitat in the UK BAP[41] and are listed under the Habitats Directive under Annex 1 Mudflats and sandflats covered by water at low tide and Sandbanks slightly covered by seawater. *Zostera* beds are also listed on the OSPAR List of Threatened &/or Declining Species and Habitats (Tullrot 2009). *Zostera marina* beds are widely distributed along the west coast of Scotland and the Hebrides, Orkney and Shetland. *Zostera marina/angustifolia* beds are well developed in the Moray and Cromarty Firths, where *Zostera noltii* beds are also present.

3.3.2 Pressures on seagrass beds

The key pressures on this feature are:

- Disease. In the 1930s large swathes of seagrass were lost to disease (Davison & Hughes 1998). The fungus and slime mould which colonised the weakened seagrass have recently reappeared in seagrass beds around the Isles of Scilly.[42]
- *Zostera* spp. are spatially dynamic. Natural cycles and events such as storms and grazing by birds can have a significant impact on the extent of *Zostera* spp.[43] It has been noted that grazing by wildfowl can have a dramatic seasonal effect with more than 60% reduction in leaf cover reported from some sites.[44]

[39] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000349
[40] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000234
[41] http://www.ukbap.org.uk/ukplans.aspx?id=35
[42] Ibid.
[43] Ibid.
[44] Ibid.

- Physical disturbance by coastal development including infrastructure, renewable energy, dredging, reclamation and moorings (Tullrot 2009).
- Water pollution from heavy metal contaminants, herbicides, antifoulants and nutrient pollution can affect productivity and quality (Davison & Hughes 1998). There is little evidence of harm by heavy metals or antifoulants but data exist on herbicides impairing growth (Davison & Hughes 1998). Excessive nutrients can drive proliferation of phytoplankton and susceptibility to disease. In this context, marine cage aquaculture could impact through copper antifouling and nutrient enrichment.
- Physical disturbance from mobile fishing gear, trampling, dredging for cockles, suction-dredging for razorfish, and bait digging can impact seagrass. Davison & Hughes (1998) note that some physical disturbance can have a positive impact and encourage new growth.

3.3.3 Management options for seagrass beds

The sensitivity of seagrass beds to turbidity is classified by OSPAR as "high", while sensitivity to other contaminants (with the exception of eutrophication) is considered "intermediate"; physical disturbance is also a major factor (Tullrot 2009). Regeneration of seagrass beds is lengthy, and recovery very slow (Davison & Hughes 1998). Thus, management of seagrass MPAs would need to consider controlling activities causing turbidity and organic enrichment in the vicinity of seagrass beds e.g. siting of marine aquaculture cages and treatment of terrestrial sources of pollution and excluding physical disturbance, e.g. trawling, dredging, and anchoring.

3.4 Native oyster beds

3.4.1 Description of native oyster beds

The native oyster (*Ostrea edulis*), JNCC listed as SS.SMx.IMx.Ost (*Ostrea edulis* beds on shallow sublittoral muddy mixed sediment),[45] is a bivalve mollusc that occurs in estuarine and shallow coastal habitats sheltered from wave action, with sediments ranging from mud to gravel. Now rare, native oyster beds are included in the UK

[45] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000788

Biodiversity Action Plan[46] and the Scottish Biodiversity List as a Priority Species, and listed on the OSPAR List of Threatened &/or Declining Species and Habitats (Haelters & Kerckhof 2009). Native oysters now occur mainly in small, scattered populations fringing the west coast sea lochs, usually at low population density. Only Loch Ryan in Galloway still supports oyster beds large enough to sustain commercial harvesting, although there are extant populations in Lochs Sween, na Keal, Ailort and around Skye. Other locations documented in the UMBS Millport (2007) report may warrant re-examination.

3.4.2 Pressures on native oyster beds

Pressures on the feature include:

- Harvesting of the resource. Hughes & Nickell (2009) concluded that the disappearance of *O. edulis* could be attributed to overexploitation. Illegal fishing has been problematic in Scotland.[47]
- *Ostrea edulis* is impacted by synthetic compound pollution and to a lesser extent heavy metal pollution.[48] The impact of TBT, potentially from past shipping and aquaculture, may have reduced populations and breeding success.
- Smothering is found to impact growth rates. Coastal infrastructure may impact on the restoration of the species.[49]
- Disease, parasites and invasive non native species have had major impacts on *O. edulis.*[50]

3.4.3 Management options for native oyster beds

Under the OSPAR classification, *O. edulis* is considered "highly sensitive" to loss of substrate, smothering, tributyl tin (TBT), introduced pathogens and parasites, introduction of non-native culture species (i.e. *Crassostrea gigas*) and over-exploitation (Haelters & Kerckhof 2009). The recovery of *O. edulis* is dependent on a number of factors including the low population density, sporadic recruitment of

---

46 http://www/ukbap.org.uk/UKPlans.aspx?ID=495
47 Ibid.
48 http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=3997#synthetic_chemicals
49 Ibid.
50 http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=3997#microbial

larvae, lack of suitable attachment sites (dead oyster shells, or "cultch"), outbreaks of parasites and infections, and continued exploitation (UMBS Millport 2007). Additionally, *O. edulis* is also commercially harvested in the one area of Scotland where it is most abundant, thus management options for this species and biotope are complex. The legal implications for protecting *O. edulis* in Scotland have been reviewed (Smith et al. 2006). Any MPA based on the native oyster, however, will need attention paid to preventing smothering, providing adequate substrate, avoiding the introduction of *Bonamia* spp., exclusion of TBT, and most importantly, prevention of unlawful harvesting. Providing exploitation is not excessive, commercial harvesting in potential MPAs should not need to be excluded. A long term approach to restoration of this species is required so the species can return to full potential with MPA instruments as potential means for increased protection and monitoring. Education of the public may also be increased by MPA activity.[51]

3.5 Burrowed deep muddy habitats

3.5.1 Description of burrowed deep muddy habitats

Burrowed deep mud (in water depths > 20 m) habitats are, like the tidally swept habitats described in Section 3.1, a combination of several similar habitats that have been combined here for the sake of ecological coherence. These habitats include seapens *Funiculina quadrangularis* and burrowing megafauna in undisturbed circalittoral fine mud (SS.SMu.CFiMu.SpnMeg.Fun),[52] seapens and burrowing megafauna in circalittoral fine mud (SS.SMu.CFiMu.SpnMeg),[53] *Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud (SS.SMu.CFiMu.BlyrAchi)[54] and burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud (SS.SMu.CFiMu.MegMax).[55] In Scottish waters there are deep mud habitats contained within several SACs such as Lochs Maddy, Duich, Long and Alsh. Mud habitats in deep water are a Priority Habitat in the UK BAP.[56] *Funiculina quadrangularis* and *Styela gelatinosa* are Priority Species in the UK BAP.[57,58]

---

[51] http://www/ukbap.org.uk/UKPlans.aspx?ID=495
[52] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001183
[53] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001218
[54] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000209
[55] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001994
[56] http://www.ukbap.org.uk/ukplans.aspx?id=41
[57] http://www.ukbap.org.uk/UKPlans.aspx?ID=317
[58] http://www.ukbap.org.uk/UKPlans.aspx?ID=590

3.5.2 Pressures on burrowed deep muddy habitats

As trawling activity has increased over time some areas of the seabed are trawled several times every year, disrupting not only the benthic communities but the biogeochemical properties and integrity of seabed sediments (cf. Jennings & Kaiser 1998, Watling & Norse 1998). Other pressures include: smothering, organic enrichment and physical disturbance (e.g. from anchoring).

3.5.3 Management options for burrowed deep muddy habitats

There are no current statutory protective measures for the seapens or sea squirts mentioned above, although seapens and burrowing megafaunal habitats are considered by OSPAR as a Priority Habitat and classed as "sensitive" (Curd 2010). As the greatest single pressure on seapens is from bottom trawling (Hughes 1998), MPA management of this marine feature would need to address this activity. This especially true for the *Nephrops* fishery, as this species coexists with seapens in much of its distribution; it is generally accepted, however, that creel fishing causes far less damage than trawling (Kinnear et al. 1996, Hughes 1998). Smothering, organic enrichment and physical disturbance (e.g. from anchoring) are also problematic for seapens and burrowing megafauna, therefore these activities would need to be controlled, especially enrichment from marine fish farming (Hughes 1998). Many of the deeper burrowing megafauna are assumed to be relatively unaffected by demersal trawling (Atkinson 1989, Greathead et al. 2007), however Howson & Davies (1991) found burrow density decreased in trawled areas of Loch Fyne compared to those where trawling was prevented.

3.6 Seamounts

3.6.1 Description of seamounts

Seamounts are defined by OSPAR as undersea mountains of volcanic origin, with a crest that rises more than 1000 m above the surrounding seafloor (McClain et al. 2009, Howell et al. 2010). Seamounts are known to influence their physical environment downstream, supply species to neighbouring shelf, slope or abyssal sediments (Norse et al. 2005, McClain et al. 2009) and act as stepping stones facilitating long-distance dispersal of species across oceans (Wilson & Kaufmann 1987), thus playing an important role in the connectivity of populations (Howell et al. 2010).

3.6.2 Pressures on seamounts

As biodiversity 'hotspots', seamount communities are vulnerable to anthropogenic impact and therefore species extinctions (Roberts et al. 2002). There can be a high degree of endemism of seamount fauna (Richer de Forges et al. 2000) making these habitats particularly sensitive to disturbances. Moreover, many of the species they support, e.g. fish, corals, cetaceans, are long-lived, late-maturing species, making them very vulnerable to overexploitation (Roberts 2002a). Fishing is one of the main threats to seamount communities: comparisons of fished and unfished communities on seamounts off Tasmania showed that heavy trawling essentially removed the coral aggregate and significantly reduced the number of species and biomass (Koslow et al. 2001).

Other threats to seamounts (and also cold-water corals, Section 3.2.2.1) include but are not restricted to (Roberts et al. 2009b):

- Cabling and pipeline laying
- Vessel anchoring
- Waste disposal from e.g. shipwrecks, oil platforms, munitions, radioactive materials, sewage sludge, dredge spoil.
- Sampling activities and scientific research
- Although the consequences are not fully understood, carbon dioxide (CO_2) sequestration programmes also pose a risk to seamount communities and the corals they support. Liquid CO_2 quickly reacts with water forming CO_2 hydrates ($CO_2.6H_2O$) in an exothermic reaction. It is generally agreed that organisms in contact with high concentrations of CO_2 would be killed (Davies et al. 2007). Over time, the hydrate would dissolve and spread through the deep ocean (Broecker & Kunzig 2008) disrupting carbonate chemistry and making seawater more acidic.

3.6.3 Management options for seamounts

Data is still limited with regard to seamounts thus the precautionary approach should be adopted when managing these features. Issues of endemism should form a central theme when developing long-term conservation strategies. Zoned MPAs including marine reserves and permanent no take zones (PNTZs) are useful management tools.

Lophelia pertusa on seamounts is listed as a Priority Species on the UK Biodiversity Action Plan[59] but seamounts are not listed as a Priority Habitat. Recent implementation of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS)[60] recommended that the UN General Assembly improve the management of vulnerable deep-sea ecosystems. Implementation of the UN declaration required that individual nations and fishery management organisations, '*protect vulnerable marine ecosystems, including cold-water corals, from disruptive fishing practices where they are known or likely to occur'*. Through the OSPAR convention,[61] seamounts (conforming to the strict definition stated earlier) are also afforded some measure of protection through being listed as a threatened and declining habitat for which OSPAR Marine Protected Areas may be established.

There is mounting evidence that 'seamounts' cannot be considered a single habitat type, and that raised features of the seabed in general need to be evaluated independently to assess their importance in a conservation context (Howell et al. 2010). Seamounts are an important part of the deep-sea ecosystem but must be used as a conservation unit for the right reasons (Howell et al. 2010). Seamount management strategies must also take into account that seamounts form critical habitat and feeding grounds for commercially important fish, cetaceans and other mobile species (see Section 3.7 on mobile species).

[59] http://www.ukbap.org.uk/ukplans.aspx?id=45
[60] http://www.un.org/depts/los/consultative_process/consultative_process.htm
[61] http://www.ospar.org/content/content.asp?menu=00500215000000_000000_000000

3.7 Mobile species

3.7.1 Description of mobile species

Mobile species are key components of marine ecosystems and biodiversity worldwide and would benefit both directly and indirectly from MPA protection. Indeed, an MPA network cannot be ecologically coherent if mobile species and their critical habitats are not included. A number of nationally and internationally important mobile species, reside in and around Scottish waters, including various seabirds, cetaceans, pinnepeds, fish such as skate and basking shark, and invertebrates. Many of these species are commercially important. See Appendix 2 for details of which mobile species reside in Scottish territorial waters, where and their current level of legal protection, and information on current status.

3.7.2 Pressures on mobile species

Most mobile species in Scottish waters are *k*-selected: they are long-lived, slow growing, reach sexual maturity late and produce few, energy-expensive young. As such they are very vulnerable to disturbance and threats, and populations recover slowly, if at all. Pressures on them include:

- Fisheries (of mobile species and/or their prey) and by-catch
- Aquaculture
- Pollution and bioaccumulation of contaminants
- International trade in marine products, e.g. shark products
- Boat collision/propeller damage: cetacean and basking sharks in particular
- Reckless or intentional disturbance
- Marine tourism/Ecotourism
- Offshore renewable energy devices
- Oil and gas exploitation
- Military activities
- Carbon capture and storage
- Climate change and associated increased seawater temperatures – this is causing biogeographical distribution shifts in the prey of many mobile species. For example, basking sharks (*Cetorhinus maximus*) prey on and actively seek

dense patches of calanoid copepods and a number of these copepods species have exhibited northern distribution shifts, some by as much as 10˚ of latitude in 50 years (Beaugrand et al. 2002), a trend which is accelerating (Edwards et al. 2008). Consequently, basking sharks are being observed further north, which can put them at risk of being caught in shark fisheries (Sims & Reid 2002, Speedie et al. 2009). Magnussen et al. (2007) reported that 5,538 kg of basking shark fins were exported from Norway in 2005.

- Ocean acidification and its effects of prey survival

3.7.3 Management options for mobile species

Nationally and internationally important mobile species can benefit from protection of habitats critical at different life stages (Duncan & Boyd 2007) but where MPAs encompassing habitats, such as those discussed in Sections 3.1 - 3.6, do not fully protect essential areas for key life stages of important mobile species, further MPA designations should be considered to ensure survival of the mobile species.

Critical habitat includes high density areas but also:

> "*those parts of a* [species'] *range, either a whole species or a particular population of that species, that are essential for day-to-day survival, as well as for maintaining a healthy population growth rate. Areas that are regularly used for feeding (including hunting), breeding (all aspects of courtship)'* delivering and *'raising* [young], *as well as, sometimes, migrating…especially if these areas are regularly used*" (Hoyt 2005).

Areas where socialising, nursing and resting take place must also be considered. Furthermore, the designation should extend to the critical habitat of mobile species' prey and to areas where important ecosystem processes occur, e.g. productive upwellings and fish spawning grounds that influence species and prey distributions.

When considering critical habitats it is essential to take into consideration human activities taking place in or near the critical habitat. If activities take place in or in close proximity to critical habitats, they will have greater impacts on the population than those further away (Roberts et al. 2003, Reeves 2009).

Further consideration should be made of movement **corridors** connecting these critical habitats. This is vital to ensure that animal hotspots do not become isolated islands of biodiversity, and is crucial to long-term population viability (e.g. Reeves 2009), especially in species with ontogenetically disjunct life stages in their life cycle (Lipcius et al. 2003).

Ecological corridors were legally defined in the U.S. (Ninth U.S. Circuit Court of Appeals (1990), (cited in Walker & Craighead 1997) as:

> "*…avenues along which wide-ranging animals can travel, plants can propagate, genetic interchange can occur, populations can move in response to environmental changes and natural disasters, and threatened species can be replenished from other areas*".

The concept of a corridor, as described in the literature, can vary from a 5 m wide strip (e.g. Hill 1995), through a kilometers-wide swathe of habitat (Felton 1996, Lipcius et al. 2003), to series of interrelated habitats, e.g. the functionally important interrelation of mangroves, seagrass and coral reefs in tropical marine systems (Good 1998).

In the marine context, corridors are intrinsically more difficult to define and manage than their terrestrial counterparts (Evans 2008) and it is possible that MPAs could be linked by virtual corridors based on conservation measures specifically addressing problems affecting the concerned species in transit, or the quality of their transiting habitat (T. Agardy cited in Evans 2008).

For the purposes of this report, an ecologically meaningful corridor is considered to be an arrangement of protected and managed critical habitat areas, either continuous or discontinuous, connecting core MPA sites, the utility of which will depend on whether they are designed to protect separate critical habitats (e.g. the breeding *and* feeding grounds of mobile species) of the *same* population (Evans 2008). It is important to note that scale and species are critical determinants. Corridors are species specific; what to a larger species may be a linear feature may become a series of stepping stones for smaller species (Good 1998, Boitani et al. 2007).

Overall, mobile species can derive benefits from MPA protection but **an adaptive management approach is essential.** Whilst the SAC series makes a contribution to securing favourable conservation status for some mobile species, wider measures are also necessary to support their conservation. SAC designation should be maintained but not preclude the inclusion of these sites in wider MPAs, e.g. seawards extensions to encompass critical habitats. Furthermore, where populations of mobile species do not meet European thresholds, MPA designations are important to protect nationally important sites for mobile species.

Of fundamental importance is that where our understanding of habitat functional roles is rudimentary, e.g. the case of cold-water corals as habitats for seabirds, cetaceans and fish, **precautionary management strategies** are also required.

Sites for mobile species that require protection include:

- Migration bottlenecks
- Breeding grounds are important in maintaining overall population size and as sources of emigration to smaller or newly-established colonies
- Nursery areas
- Feeding/foraging grounds
- Resting areas or haul outs
- Concentrations of non-breeding individuals (e.g. over-wintering populations)
- Foraging and migration corridors

Measures that could be adopted for mobile species include:

- Identification of critical habitats
- Appropriate Environmental Impact Assessments
- Temporal closures
- Permanent, high level protection for critical habitats or areas – e.g. permanent no take zones or marine reserves surrounded by buffer zones of medium

protection in turn surrounded by zones with low level protection but within which sustainable use is encouraged

- Zonation
- Corridors between protected areas and networking of MPAs
- Seaward extension of existing land-based site protection (e.g. SSSIs) to protect, e.g. seabird and/or pinniped colonies
- Gear bans and by-catch mitigation devices imposed (e.g. by-catch mitigation measures)
- Scientific research and monitoring, including public sighting initiatives
- Reviews to assess the efficacy of the conservation objectives of the MPA and adapt the management approach as necessary. Adaptive management should occur in preference to de-selection
- Training of (eco)tourism operators
- Promotion of existing codes of conduct and practical guidance, e.g. the Scottish Marine Wildlife Watching Code (SMWWC)[62]
- Vessel type and speed restrictions in critical habitats (seasonal or permanent), e.g. maximum speed limits in basking shark habitats.

[62] http://www.marinecode.org/

4 Management recommendations

4.1 Overview

In this section we highlight recommendations for the management of Nature Conservation MPAs. The section examines in detail options from Table 2, in particular regulatory levers that will influence MPA management, general recommendations to observe when building MPA management objectives and plans, and finally some conclusions on navigating the complexity of the MPA debate. This section should be read in conjunction with Table 1 and Table 2 in the executive summary.

Through the provision of the Marine (Scotland) Act 2010, significant reforms to marine governance and biodiversity conservation are making their way through the 3 pillar approach. In terms of the wider seas and the species pillar, the duty on ministers and authorities to ensure the ‘sustainable development and protection and enhancement’ of the Scottish marine area provides the incentive to implement national and regional marine plans under Part 3 of the Act. Marine planning will be critical to ensure the spatial management of commercial activities and will influence the success of Scottish Nature Conservation MPAs (MPA). In terms of the site protection pillar, the development of MPAs under Part 5 of the Act is a major area of legislative reform. The development of conservation objectives, management plans and conservation orders will be an important process to ensure that species and habitats of Scottish importance are conserved in an ecologically coherent manner and damaging activities are managed.

4.2 ‘Wider Seas’ tools to manage Nature Conservation MPAs.

Table 2 in the executive summary highlights the options for the management of activities within and external to MPAs. The table details a number of regulatory levers that can be used to control and manage activities that impact on priority marine features. At present the protection of features is considered too low and uncoordinated - joined up thinking across policy instruments is urgently required.

As described in Halpern et al. (2010) the effectiveness of instruments outside MPA planning is a critical determinant of MPA success. This emphasizes the importance of the '3 pillar approach' to ensure consistent impact mitigation, management and protection of features within and outside MPAs. It is important that the array of existing policy and voluntary tools across different sectors respond and adapt to the development of nature conservation MPAs under the Marine (Scotland) Act 2010. The idea of joined up governance is fundamental to ensure conservation outcomes are delivered on priority marine features regardless to where they occur. We propose that planning for priority marine features and MPAs clearly articulates the appropriateness and effectiveness of policy instruments that will influence management. Table 2 lists a number of options to achieve this across different areas of activity, we expand on some of these below.

Drawing on the example of fisheries, when it comes to the impact on priority marine features, the Inshore Fishing (Scotland) Act 1984 provides a number of options for management. This Act enables Ministers to regulate fishing in inshore waters by prohibiting combinations via control measures of the following:

- all fishing for sea fish
- fishing for a specified description of sea fish
- fishing by a specified method
- fishing from a specified description of fishing boat
- fishing from or by means of any vehicle, or any vehicle of a specific description
- fishing by means of a specified description of equipment
- Ministers may also specify the period during which prohibitions apply, and any exceptions to any prohibition

The Act was amended by the Environment Act 1995[63] so that it may restrict fishing for "marine environmental purposes" (rather than for solely fishery management).[64] "Marine environmental purposes" are described as "conserving or enhancing the natural beauty or amenity of marine or coastal areas or of any features of

[63] http://www.opsi.gov.uk/acts/acts1995/ukpga_19950025_en_1
[64] See: http://www.opsi.gov.uk/acts/acts1995/ukpga_19950025_en_13#pt5-pb5-l1g102

archaeological or historic interest in such areas; or of conserving flora and fauna which are dependent on, or associated with, a marine or coastal environment." Orders under the Act could be used to minimise impacts upon features within (and outside) MPAs by managing damaging activities through spatial and temporal restrictions. Restrictions should relate to the ecological requirements of the feature, such as recovery potential, and be based on clear scientific evidence. Existing measures where the Act has been used include areas where mobile gear is excluded for all or part of the year, and restrictions on the size of vessels permitted for certain fisheries in certain areas. For example, in 2007 a statutory instrument under the Act was implemented in the Firth of Lorn SAC to restrict scallop dredging.[65] Another example of a temporal and spatial restriction of activities occurred in the Loch Creran SAC[66] to minimise impacts of mobile gear on biogenic reefs. However it is important to note that a range of other commercial activities still occur (e.g. aquaculture and recreation) that require management intervention. In addition, impacts from non-point sources of pollution require adequate management responses such as the Water Framework Directive.

The Sea Fisheries (Shellfish) Act 1967 grants ministers the powers to implement regulating orders for shellfish. These orders are of significance in the management of shellfish and can also have broader conservation benefits, such as regulating damaging activities and preparing management plans. The Act was amended in 2000 to allow fishing activities with lesser impacts, such as creeling or diving, to take place and reduce conflict between gear types. An example is the Loch Crinan Scallops Fishery Order 2005[67] that establishes a fishery for dived scallops and excludes other activities. This instrument could be used to control the use of gear types that would impact priority marine features in inshore waters and would complement an MPA designation under the Marine (Scotland) Act 2010. These orders have been used several times in regions such as Shetland, the Solway and the West Coast to implement management reform but require formal application, consultation and regulatory impact assessment. It is important to note that orders from the Inshore Fishing (Scotland) Act and the Sea Fisheries (Shellfish) Act are developed on the prerogative of the minister and are therefore subject to political will. Any

[65] http://www.oqps.gov.uk/legislation/ssi/ssi2007/ssi_20070186_en_1
[66] http://www.opsi.gov.uk/legislation/scotland/ssi2007/ssi_20070185_en_1
[67] http://195.99.1.70/legislation/scotland/ssi2005/20050304.htm

implementation of a new order will require significant momentum and consultation if it is to exclude existing activities and be based on scientific assessments of the impact of activities on the ecological requirements of the protected feature.

Another alternative strategy for fisheries and other sectors is to proactively engage in including impact mitigation measures and strategies into Inshore Fisheries Group (IFG) management plans. This would signal that the interested parties and the industry are engaging in the conservation of marine habitats and species and are considering broader issues in the (yet to be written) management plans. While the proposed IFG management plans have no legal 'teeth' they potentially recommend management measures to the Minister, including statutory responses.[68] This would be a clear signal by the industry that priority features and MPAs are factored into inshore fisheries management. We recommend that the links between IFGs, marine planning and MPAs be explored and clarified.

A looming challenge is the management of fishing and aquaculture activity that could impact offshore MPAs. While inshore fleets are covered by Scottish regulations (assuming there is political will to develop regulations) offshore fishing is covered predominantly by the EU Common Fisheries Policy (CFP). While a mechanism exists for addressing a variety of impacts upon species and habitats of EU importance under the Offshore Marine Conservation Regulations 2007/2010, the Common Fisheries Policy is the dominant regime for managing fishing activity in the offshore zone. The Scottish and UK Government will be required to work with the European Commission seeking closure or modification to fishing activity in offshore regions.[69] Further reform will be necessary to ensure Scottish priority marine features in the offshore zone can be protected from impacts from a range of commercial activities.

It should be noted that there is significant potential for industry to demonstrate environmental responsibility through market and voluntary mechanisms such as certification schemes (for example the Marine Stewardship Council) that rewards fishermen for sustainable behaviour. In addition, mechanisms such as the Conservation Credits Scheme and Real Time Closures have been cited as generally

[68] http://www.scotland.gov.uk/Topics/marine/Sea-Fisheries/InshoreFisheries/IFGsMap/IFGsConstitution
[69] http://www.jncc.gov.uk/page-4550

successful and have encouraged the industry to develop novel approaches to delivering conservation outcomes. There is an opportunity for all maritime sectors to demonstrate best practice and develop voluntary approaches that minimise impacts upon marine environments and encourage investment and innovation in the industry (for example through real time monitoring and/or gear modification). We encourage the development of these and similar market or voluntary schemes that promote the mutual goals of a healthy ecosystem and sustainable fishing industry and do not solely rely on centralised regulation.

Other examples of the value of 'joined-up thinking' are evident in Table 2. The development of coastal infrastructure can have impacts on marine features that range from physical disturbance, through increased turbidity, to altered hydrology. EIAs and SEAs for new developments should include marine features and MPAs in the assessment of the activity in order to ensure that mitigation measures are incorporated at the earliest stages of development planning. The inclusion of MPAs in the National Planning Framework and relevant strategic and local plans under the Planning etc. (Scotland) Act 2006 will also strengthen MPA management and ensure these considerations are included at a strategic and operational scale – particularly impacts that come from terrestrial and or coastal systems.

4.3 Marine planning under the Marine (Scotland) Act 2010

Marine spatial planning (MSP) will be critical for influencing the spatial extent and license regime for many maritime activities, including activities that have not been regulated in the past such as marine leisure and tourism. Although MSP is yet to be implemented in Scottish seas, we see it as providing the overall vision for a marine region, and the policy 'glue' that will coordinate activities within, or in proximity to MPAs and broader activities. Marine planning must underpin integrated and joined up thinking across sectors and conservation outcomes - it is imperative that this be adequately resourced, consultative, transparent and science-based.

Part 2 of the Act specifies the duty of ministers and public authorities to ensure the 'sustainable development and protection and enhancement' of the Scottish marine area, while Part 3 highlights the duty for the mitigation of and adaptation to climate change. Under s.5 of the Act[70] Scottish ministers must prepare a national marine plan and may prepare regional marine plans. Section 5(3) of the Act provides that a marine plan states policies for the sustainable development of the area to which it applies and the contribution of nature conservation MPAs (see discussion above in Section 4.2). The Act specifies the content of plans. Ministers must:

(a) Set:

(i) Economic, social and marine ecosystem objectives,

(ii) Objectives relating to the mitigation of, and adaptation to, climate change,

(b) Prepare an assessment of the condition of the Scottish marine area or Scottish marine region,

(c) Prepare a summary of significant pressures and the impact of human activity on the area or region.

The development of marine plans will be important strategic instruments, but it is unclear that in their delivery they will drive concerted and integrated regional actions – particularly if the development of regional plans is voluntary. The Act highlights that decisions must be in 'accordance with', or 'have regard to', the marine plan. Under s.15 of the Act:

(1) A public authority must take any authorisation or enforcement decision in accordance with the appropriate marine plans, unless relevant considerations indicate otherwise.

(2) If a public authority makes an authorisation or enforcement decision otherwise than in accordance with the appropriate marine plans, it must state its reasons.

(3) A public authority must have regard to the appropriate marine plans in making any decision:

(a) which relates to the exercise by them of any function capable of affecting the whole or any part of the Scottish marine area, but

(b) which is not an authorisation or enforcement decision.

[70] www.oqps.gov.uk/legislation/acts/acts2010/pdf/asp_20100005_en.pdf

While no plans yet exist (the national marine plan will be drafted in spring 2011), clearly the 'devil will be in the detail' in terms of the development of plans and the alignment of decisions with objectives. It appears that most 'authorisation and enforcement' decisions, i.e. decisions relating to development applications and licensing, will be in line with marine plans, but material considerations may be used to deviate from a plan's objectives. Any deviation will undergo scrutiny, however the Act does not state what 'relevant' considerations would include, allowing a degree of flexibility into the interpretation. In terms of the other (i.e. non-enforcement and non-authorisation) decisions and actions (s.15(3)) that public authorities undertake, this may include strategic planning and statutory decisions under other instruments that were discussed above in Section 4.2.[71] The authority must 'have regard to' the appropriate plan when making such a decision. It is not clear at this stage what this implies, but taking a parallel with local government planning, an interpretation is that the plan could provide non-statutory or statutory guidance to making decisions and must be justified in the decision. This is clearly a critical process in terms of delivering successful nature conservation MPAs and the alignment of policies and decisions with ecological objectives. The entire process, from formulation, objective setting and decision making, should be transparent and scrutinised to ensure that conservation considerations are prominent in plan making and delivery.

4.4 Managing Nature Conservation MPAs under the Marine (Scotland) Act 2010

Under the Marine (Scotland) Act s.67(1), Scottish ministers may designate Nature Conservation MPAs (MPA) in Scottish territorial waters (out to 12 nm) and under the UK Marine and Coastal Access Act 2009 will have devolved authority to designate marine conservation zones in offshore waters. While the selection of individual sites is discretionary, the Act specifies a clear duty for Ministers to implement a network of sites that contributes to the conservation or improvement of the marine environment (s.79). Draft guidance published by Marine Scotland 2010(a), highlights the objectives for the network:

[71] The UK Marine Policy Statement : A draft for consultation (July 2010) gives an example of such decisions as "decisions about what representations they [a public authority] should make as a consultee or about what action they should carry out themselves".

- *The MPA network should be capable of delivering Scotland's MPA commitments, including national and international priorities for the conservation of priority marine features.*

- *The purpose of the MPA network will be to deliver benefits for marine natural features and to support wider ecosystem function within the context of a 3 pillar approach. The network should safeguard marine natural features (relating to both biodiversity and geodiversity) in Scottish waters and, through sound management, deliver recovery where practicable.*

- *The presence of priority marine features will underpin the selection of Nature Conservation MPAs but preference will be given to the selection of areas with multiple features.*

- *MPAs forming part of the network will be managed so as to deliver long-term protection to the marine natural features they contain. An MPA network will contribute to Government objectives on the environment, as well as to broader objectives, including sustainable economic growth.*

If Ministers decide to create a nature conservation MPA then they must state the conservation objectives (s.68(3)) and have regard to the extent to which the designation would contribute towards the development of a network of conservation sites (s.68(4)). While no guidance exists in the Act on the content of said objectives, we would assume conservation objectives would lay out the short, medium and long term aspirations and targets for: the recovery of individual species, groups of species and habitats; identification of threatening processes and management options; and contribution to a broader network of ecologically coherent sites (under s.79). Objectives should be backed by scientific indicators and performance measures as outlined in recent Marine Scotland research.[72] Ministers may have regard to the extent to which a designation will contribute to the mitigation of climate change (s.68(4)) and this should also be reflected in the objectives for a site. The performance of the designation against the objectives is assessed 'from time to time' (s.70) and a full report on all MPA designations and performance is presented to Parliament (s.100). Sections 82 and 83 specify a duty on public authorities to exercise their functions in a manner that furthers conservation objectives and for decisions they make to not significantly impact upon MPAs, in addition to developing a marine management scheme (s.99) to further the conservation objectives of an MPA.

[72] http://www.scotland.gov.uk/Publications/2010/03/30180908/0

Marine conservation orders (in combination with wider seas measures) have the potential to control damaging activities in MPAs. Under s.85 of the Act, Scottish Ministers may establish marine conservation orders for furthering the conservation objectives of an MPA. Scottish Ministers have a duty to assess the impact of the restriction of activities under such orders (s.91). There are also provisions for "urgent orders" in s.88 of the Act. Orders can include (s.86):

Prohibiting, restricting or regulating:

(a) entry into or movement, activity or works in the area protected by the order by a:
(i) person, (ii) animal, (iii) vessel,
(iv) vehicle or thing (or a specified type of vehicle or thing),
(b) the anchoring of any vessel (or types of vessel) within the protected area (including the fixing of moorings or anchors to the seabed),
(c) the killing, taking, destruction, molestation or disturbance of animals or plants of any description in the protected area,
(d) the removal of all or part of any thing (or category of things) from the protected area, including in particular all or part of a marine historic asset,
(e) the depositing (by any means) of anything in a protected area,
(f) the doing of anything in the protected area which, in the opinion of the Scottish Ministers, may—
(i) interfere with or damage the seabed,
(ii) damage or disturb any object in the protected area
(iii) otherwise cause harm to the protected area.

The designation of MPAs, conservation objectives, and marine conservation orders have the potential to radically change the face of marine conservation. While MPA activity will focus on the inclusion of representative priority marine features of Scottish and UK importance, the Act specifies that other designations such as Habitat Directive sites (SACs, SPAs) and Scottish sites such as SSSIs will be included in the overall network. The Act may also trigger stronger management measures and control measures for existing European designations through the development of conservation orders.[73]

[73] For example s85.1(d) highlights that marine conservation orders can be developed for nature conservation MPAs that include European marine sites.

Fundamentally, the use of the instruments in the Act requires political will to be successful. The selection of new sites of Scottish importance that are additional to existing SACs and SPAs, the application of wider seas measures from other pieces of legislation, and the implementation of marine conservation orders all require the approval of Scottish ministers. It has been observed that of the current European marine sites in Scotland, 7 out of 28 have developed management groups. For offshore sites in the UK, no management groups have been established (although it should be pointed out that these sites are in progress or recently appointed). The use of management plans for European sites appears to be a least favored option by the SNH or the Minister, and the SNH website clearly states that management schemes for European marine sites are only established if there is a benefit to the site. Carrying this logic forward, it is assumed that conservation orders and management plans will only be used under the Marine (Scotland) Act if there is a direct benefit to the site and the Minister deems it appropriate to act. We reiterate that if damaging activity is occurring to priority marine features, the regulatory levers of wider seas measures such as the Inshore Fishing (Scotland) Act or conservation orders under the Marine (Scotland) Act will be increasingly required to ensure the success of nature conservation MPAs.

4.5 Climate change-related recommendations for MPA management

Abundant evidence exists of changes in marine ecosystems due to direct and indirect effects of climate change (Roberts et al. 2009b). Some of these changes include: ocean warming, ocean acidification, sea level rise, changes in the current climate variability, and freshwater influx (Keller et al. 2009). However, while there is yet little concrete evidence on how protected areas in general will perform in the face of climate change (Heinz Centre 2008) planning for climate change in the context of MPAs is even more problematic because it is a relatively recent endeavour (McLeod et al. 2009).

The uncertainties created by climate change mean that the boundaries of protected areas may need to be flexible in time and space. Movable protection is particularly relevant for marine systems where frontal zones and currents are likely to shift with climate change and where the areas involved are potentially enormous (Hannah 2008). The management objectives of protected areas will also need to be dynamic and adaptive so that they change as their composition changes over time (Campbell et al. 2008). Some general recommendations on MPA management within the context of climate change are provided below in Table 4 and follow from Keller et al. (2009):

Table 4. Management options for MPA managers in the context of climate change (Keller et al. (2009) based on McLeod et al. (2009)).

Management options for MPA managers in the context of climate change
Manage human stressors such as fishing and inputs of nutrients, sediments, and pollutants within MPAs.
Improve water quality by raising awareness of adverse effects of land-based activities on marine environments, implementing integrated coastal and watershed management, and developing options for advanced wastewater treatment.
Manage functional species groups necessary to maintaining the health of reefs and other ecosystems.
Identify and protect areas that appear to be resistant to climate change effects or to recover from climate-induced disturbances.
Identify and protect ecologically significant (‘‘critical’’) areas such as nursery grounds, spawning grounds, and areas of high species diversity.
Identify ecological connections among ecosystems and use them to inform the design of MPAs and management decisions such as protecting resistant areas to ensure sources of recruitment for recovery of populations in damaged areas.
Design MPAs with dynamic boundaries and buffers to protect breeding and foraging habits of highly migratory and pelagic species.
Establish dynamic MPAs defined by large-scale oceanographic features such as oceanic fronts where changes in types and abundances of organisms often occur.
Maximize habitat heterogeneity within MPAs and consider protecting larger areas to preserve biodiversity, ecological connections among habitats, and ecological functions.
Include entire ecological units (e.g., coral reefs with their associated mangroves and seagrasses) in MPA design to help maintain ecosystem function and resilience.
Ensure that the full breadth of habitat types is protected (e.g., fringing reef, fore reef, back reef, patch reef).
Replicate habitat types in multiple areas to spread risks associated with climate change.

Furthermore, the US Marine Protected Areas Federal Advisory Committee provided recommendations for the US National System of MPAs, relating to the effects of climate change on the oceans (National MPA Center 2008), as detailed in Table 5.

Table 5. Recommendations for evaluation and adaptive management of MPAs (National MPA Center 2008).

Recommendations for evaluation and adaptive management of MPAs
Build and enhance capacity to monitor and evaluate effects of climate change on MPAs
Enhance predictive capabilities of climate change impacts
Promote high level of coordination amongst resource and environmental agencies
Facilitate education and public engagement to expand awareness and understanding
Identify ecological thresholds that would trigger certain management responses to ensure they are timely and appropriate
Support the ecosystem characterization of MPAs to promote the improved understanding of the impact of climate change on the structure, diversity and function of MPA ecosystems.
Support adaptive management of the National System of MPAs and networks of MPAs by closing critical gaps in scientific knowledge of climate change in the ocean.
Develop the use of ocean observing systems, sensors, geospatial tools, marine spatial planning, and other predictive capabilities.

4.6 General recommendations for sound MPA management

During the preparation of this document several themes have emerged in terms of recommendations for sound marine MPA management. We highlight the key recommendations below:

Recommendation #1

Damaging activities within sites must be managed, and on the other side, activities that are harmonious and have minimal impacts should be encouraged. All activities, impacts and ecological processes should be monitored in MPA sites and be the basis of adaptive (co) management, particularly in the context of climate change.

Recommendation #2

A precautionary management approach must be adopted where there is a lack of data, and where our understanding of habitat functional roles is rudimentary. Again, this is crucial in the context of climate change.

Recommendation #3

Base MPA management and decision-making on the best currently available scientific knowledge from various branches of science, including ecological, social, and economic (Cicin-Sain & Belfiore 2005).

Recommendation #4

Continuously invest in MPA research, including ecological, social, and economic considerations (Angulo-Valdés & Hatcher 2010).

Recommendation #5

Long term monitoring must be carried out, including recovery studies, because protected areas are only effective if they are monitored. Monitoring allows for adaptive management of MPAs. However, we acknowledge that monitoring is challenging in regions far from shore, in deep-water and for offshore seamounts, for example.

Recommendation #6

Encourage opportunities for appropriate access to and/or compatible use of marine resources consistent with MPA management plans. If damaging activity is occurring to priority marine features, the regulatory levers of wider seas measures such as the Inshore Fishing Act or conservation orders under the Marine (Scotland) Act will be increasingly required to ensure the success of NC-MPAs. Zoning and spatial planning can be used to manage, restrict or exclude activities incompatible with MPA conservation. Options include spatial management and the use of buffer zones. No-take zones which are permanently protected from all preventable anthropogenic threats will be appropriate in some cases.

Recommendation #7

Implementation of a new order will require significant momentum and consultation if it is to exclude existing activities and be based on scientific assessments of the impact of activities on the ecological requirements of the protected feature. Orders from the Inshore Fishing (Scotland) Act and the Sea Fisheries (Shellfish) Act are developed on the prerogative of the minister and are therefore subject to political will. Fundamentally, the use of the instruments in the [Marine (Scotland)] Act also require political will to be successful.

Recommendation #8

Another alternative strategy for fisheries and other sectors is to proactively engage in including impact mitigation measures and strategies into Inshore Fishing Group (IFG) management plans. This would be a clear signal by the industry that priority features and MPAs are factored into inshore fisheries management. We recommend that the links between IFGs, marine planning and MPAs be explored and clarified.

Recommendation #9

It is essential to ensure that the ecological requirements of species are met through long-term MPA design and management. A coherent MPA network must include sites and critical habitats that are fundamental to the survival of mobile species. MPA sites should be linked by corridors for improved recruitment and movement of mobile species.

Recommendation #10

Clearly define MPA objectives in a transparent and inclusive manner. Establishing clear objectives is critical, builds trust, and allows for assessment of an MPA's success. Clearly stated conservation objectives from the outset will facilitate public involvement in MPAs, enable provisions for compensating those displaced from an MPA through appropriate mechanisms and allow for a meaningful assessment of MPA effectiveness (Angulo-Valdés & Hatcher 2010) under the Marine (Scotland) Act.

Recommendation #11

Commit to creating common understanding and interpretation of the significance of MPAs among stakeholders. If this is not achieved, MPA management will likely be beset with tension and threaten community stability (Oracion et al. 2005).

Recommendation #12

Commit to increased public awareness about ecosystem functioning and the role of MPAs (Angulo-Valdés & Hatcher 2010). This is also very important in the context of climate change.

4.7 Conclusion: Navigating the complexity of the MPA debate

When the first attempt to implement the 1999 California Marine Life Protection Act to establish MPAs ended in contention, one of the reasons for the failure was identified as the polarisation of a community of stakeholders into coalitions of proponents and opponents of MPAs (Weible 2008). A similar polarisation of attitudes is currently evident in Scotland with conservation proponents and industry opponents of MPAs. This sweeping generalisation by no means portrays an accurate picture of the situation, but on a very broad-brush level, this is one view of the state of affairs.

Keeping in mind this caveat, the broad-brush picture continues as follows: conservationists fear that undue weight will be given to economic considerations and thus compromise sound management measures. On the other side, taking the UK fishing industry as an example, they fear that yield reductions from the loss of access to no-take MPAs are very unlikely to be compensated for through spillover from MPAs (Jones 2008). The situation is complex since fishing is both the key cause of the concerns on which no-take MPA calls are based and the main activity that such designations will exclude (Hussain et al. 2010).

We highlight these fears in order to acknowledge that there are legitimate grounds for them on both sides and in the hope that bringing such difficult issues out into the open may facilitate participatory interactions between all affected parties, and, in time, perhaps agreement on how to frame the challenge of MPA management. We feel that it is important to frame the challenge *before* attempting to implement sound management. While science is the driver, we must take communities and stakeholders along with us on the journey and be clear about the impacts and benefits.

We acknowledge and support that science is the primary driver for the identification and designation of suitable sites for inclusion into the network and that social and economic considerations can come into play when choosing between locations that would make an equivalent contribution to the network. When considering MPAs, only when it is clear that the ecological requirements of the network can be met, will social and economic considerations figure in the decision making process - the clear legal obligation in the Act is to create a network of sites. We also acknowledge and support that under the Act, as assessment must be carried out of the social and economic impacts of declaring sites – in fact, this is a critical step to enable the application of control measures, management plans, and promote changes in industry practices. Damaging activities within sites must be managed, and on the other side, activities that are harmonious and have minimal impacts should be encouraged. All activities, impacts and ecological processes should be monitored in MPA sites and be the basis of adaptive management. Again, we strongly encourage the use of regulatory and voluntary instruments to achieve the outcomes of healthy and productive marine ecosystems that benefit current and future generations. We invite all those with an interest in the sustainable development of the sea to come forward and participate in creating a successful and ecologically coherent suite of Nature Conservation MPAs in Scotland.

5 References

Ambariyanto, Seed R (1991) The infestation of *Mytilus edulis* Linnaeus by *Polydora ciliata* (Johnston) in the Conway Estuary, North Wales. J Molluscan Stud 57:413-424

Angulo-Valdés JA, Hatcher BG (2010) A new typology of benefits derived from marine protected areas. Mar Policy 34:635-644

Anwar NA, Richardson CA, Seed R (1990) Age determination growth rate and population structure of the horse mussel, *Modiolus modiolus*. J Mar Biol Assoc UK 70:441-457

Association pour l'Etude et la Conservation des Sélaciens, Curd A, (2009) Background document for basking shark *Cetorhinus maximus*. OSPAR Commission, 36 pp.

Atkinson RJA (1986) Mud-burrowing megafauna of the Clyde Sea area. Proc R Soc Edinb Sect B (Biol) 90:351-361

Atkinson RJA, (1989) Baseline survey of the burrowing megafauna of Loch Sween PMNR and an investigation of the effects of trawling on the benthic megafauna. Report to the Nature Conservancy Council from the University Marine Biological Station, Millport. 65 pp.

Auster PJ (2005) Are deep water corals important habitats for fishes? In: Freiwald A, Roberts JM (eds) Cold-water corals and ecosystems. Springer-Verlag, Berlin, Heidelberg, p 747-760

Auster PJ, Langton RW (1999) The effects of fishing on the fish habitat. In: Benaka L (ed) Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Bethesda, p 150-187

Barbera C, Bordehore C, Borg JA, Glémarec M, Grall J, Hall-Spencer J, de la Huz C, Lanfranco E, Lastra M, Moore PG, Mora J, Pita ME, Ramos-Esplá AA, Rizzo M, Sánchez-Mata A, Seva A, Schembri PJ, Valle C (2003) Conservation and management of northeast Atlantic and Mediterranean maerl beds. Aquatic Conservation: Marine and Freshwater Ecosystems 13:S65-S76

Beaugrand G, Reid PC, Ibanez F, Lindley JA, Edwards M (2002) Reorganization of North Atlantic marine copepod biodiversity and climate. Science 296:1692-1694

Beukema JJ (1992) Expected changes in the Wadden Sea benthos in a warmer world: Lessons from periods with mild winters. Neth J Sea Res 30:73-79

Birkett DA, Maggs CA, Dring MJ, (1998) An overview of dynamics and sensitivity characteristics for conservation management of Marine SACs (volume V), Maerl Beds. UK Marine SACs Project. Scottish Association for Marine Science, 116 pp.

Bohnsack JA (1998) Application of marine reserves to reef fisheries management. Aust J Ecol 23:298–304

Boitani L, Falcucci A, Maiorano L, Rondinini C (2007) Ecological networks as conceptual frameworks or operational tools in conservation. Conserv Biol 21:1414-1422

Bokn TL, Moy FE, Murray SN (2009) Long-term effects of the Water-Accomodated Fraction (WAF) of diesel oil on rocky shore populations maintained in experimental mesocosms. Bot Mar 36:313-320

Brander K (1981) Disappearance of common skate *Raia batis* from Irish Sea. Nature 290:48-49

Breeze H, Davis DS, Butler M, Kostylev V, (1997) Distribution and status of deep-sea corals off Nova Scotia. Ecology Action Center, Halifax, NS, Canada, Marine Issue Comm Spec Publ 1, 58 pp.

Brennan R, Potts T, Mee L, (2010) Report on social and economic objectives for a Scottish Marine Plan. Marine Scotland, The Scottish Government, 180 pp.

Broecker WS, Kunzig R (2008) Fixing climate: what past climate changes reveal about the current threat – and how to counter it. Hill & Wang, New York

Bruner AG, Gullison RE, Rice RE, da Fonseca GAB (2001) Effectiveness of parks in protecting tropical biodiversity. Science 291:125-128

Bull B, Doonan I, Tracey D, Hart A (2001) Diel variation in spawning orange roughy (*Hoplostethus atlanticus*, Trachichthyidae) abundance over a seamount feature on the north-west Chatham Rise. N Z J Mar Freshwat Res 35:435-444

Cailliet GM, Andrews AH, Burton EJ, Watters DL, Kline DE, Ferry-Graham LA (2001) Age determination and validation studies of marine fishes: do deep-dwellers live longer? Exp Gerontol 36:739-764

Campbell A, Kapos V, Chenery A, Kahn SI, Rashid M, Scharlemann JPW, Dickson B, (2008) The linkages between biodiversity and climate change mitigation. A review of the recent scientific literature. UNEP World Conservation Monitoring Centre, 69 pp.

Carter DW (2003) Protected areas in marine resource management: another look at the economics and research issues. Ocean Coast Manage 46:439-456

Cicin-Sain B, Belfiore S (2005) Linking marine protected areas to integrated coastal and ocean management: A review of theory and practice. Ocean Coast Manage 48:847-868

Clark J, Dolman S, Hoyt E, (2010) Review of information and recommendations relating to Marine Protected Areas for cetaceans in UK waters (to include England, Scotland and Wales). Whale and Dolphin Conservation Society report (in prep)

Coen LD, Brumbaugh RD, Bushek D, Grizzle R, Luckenbach MW, Posey MH, Powers SP, Tolley SG (2007) Ecosystem services related to oyster restoration. Mar Ecol Prog Ser 341:303-307

Compagno LJV (1984) FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1. Hexanchiformes to lamniformes, Fisheries Synoposis, No. 125, Vol. 4, Part 1. FAO, Rome

Costanza R, Cumberland J, Daly H, Goodland R, Norgaard R (1997) An introduction to ecological economics. St. Lucie Press

Costello MJ, McCrea M, Freiwald A, Lundälv T, Jonsson L, Bett BJ, Weering TCEv, Haas Hd, Roberts JM, Allen D (2005) Role of cold-water *Lophelia pertusa* coral reefs as fish habitat in the NE Atlantic. In: Freiwald A, Roberts JM (eds) Cold-water corals and ecosystems. Springer-Verlag, Berlin, Heidelberg, p 771-805

Curd A, (2010) Background document for seapen and burrowing megafauna communities. OSPAR Commission, 27 pp.

Davies AJ, Roberts JM, Hall-Spencer J (2007) Preserving deep-sea natural heritage: Emerging issues in offshore conservation and management. Biol Conserv 138:299-312

Davison DM, Hughes DJ, (1998) *Zostera* biotopes (volume I). An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association for Marine Science (UK Marine SACs Project), 95 pp.

De Santo EM, Jones PJS (2007) The Darwin Mounds: from undiscovered coral to the development of an offshore marine protected area regime. In: George RY, Cairns SD (eds) Conservation and adaptive management of seamount and deep-sea coral ecosystems. University of Miami, Miami, p 147-156

Dixon JA, Sherman PB (1990) Economics of protected areas: A new look at benefits and costs. Earthscan Publications Ltd

Dodd J, Baxter L, Hughes DJ (2009) Mapping *Serpula vermicularis* (Polychaeta: Serpulidae) aggregations in Loch Teacuis, western Scotland, a new record. Mar Biol Res 5:200 - 205

Druffel ERM, Griffin S, Witter A, Nelson E, Southon J, Kashgarian M, Vogel J (1995) Gerardia: Bristlecone pine of the deep-sea? Geochim Cosmochim Acta 59:5031-5036

Duncan C, Boyd B, (2007) Finding NIMAS. The case for nationally important marine areas. Scottish Environment Link, 35 pp.

Edwards M, Johns DG, Beaugrand G, Licandro P, John AWG, Stevens DP, (2008) Ecological Status report: results from the CPR survey 2006/2007. SAHFOS Technical Report 5, 8 pp.

Evans PGH (2008) Selection criteria for marine protected areas for cetaceans. In: Evans PGH (ed) European Cetacean Society 21st Annual Conference. European Cetacean Society, San Sebastian, Spain, p 106

Felton M (1996) Natura 2000 - The ecological network of the European Union: using buffer areas and corridors to reinforce core areas designated by member states. In: Nowicki P, Bennett G, Middleton D, Rientjes S, Wolters R (eds) Perspectives on Ecological Networks. European Centre for Nature Conservation, Tilburg, p 133-141

Ferreira JG, Sequeira A, Hawkins AJS, Newton A, Nickell TD, Pastres R, Forte J, Bodoy A, Bricker SB (2009) Analysis of coastal and offshore aquaculture: Application of the FARM model to multiple systems and shellfish species. Aquaculture 292:129-138

Fosså JH, Mortensen PB, Furevik DM, (2000) *Lophelia* korallrev langs norskekysten forekomst og tilstand. Prosjecktrapp Havforskningsinst., 94 pp.

Fosså JH, Mortensen PB, Furevik DM (2002) The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. Hydrobiologia 471:1-12

Gass SE, Roberts JM (2006) The occurrence of the cold-water coral *Lophelia pertusa* (Scleractinia) on oil and gas platforms in the North Sea: Colony growth, recruitment and environmental controls on distribution. Marine Pollution Bulletin 52:549-559

Gell FR, Roberts CM (2003) Benefits beyond boundaries: the fishery effects of marine reserves. Trends Ecol Evol 18:448-455

Goni R, Hilborn R, Diaz D, Mallol S, Adlerstein S (2010) Net contribution of spillover from a marine reserve to fishery catches. Mar Ecol Prog Ser 400:233-243

Good JA, (1998) The potential role of ecological corridors for habitat conservation in Ireland: a review. 72 pp.

Greathead CF, Dorman DW, Mair JM, Saunders GR (2007) The sea pens *Virgularia mirabilis*, *Pennatula phosphorea* and *Funiculina quadrangularis*: distribution and conservation issues in Scottish waters. J Mar Biol Assoc UK 87:1095-1103

Haelters J, Kerckhof F, (2009) Background document for *Ostrea edulis* and *Ostrea edulis* beds. OSPAR Commission, 22 pp.

Hall-Spencer JM, Kelly J, Maggs CA, (2010) Background document for maërl beds. OSPAR Commission, 36 pp.

Hall-Spencer JM, Moore PG (2000a) *Limaria hians* (Mollusca: Limacea): a neglected reef-forming keystone species. Aquat Conserv: Mar Freshwat Ecosyst 10:267–277

Hall-Spencer JM, Moore PG (2000b) Scallop dredging has profound, long-term impacts on maerl habitats. ICES J Mar Sci 57:1407-1415

Hall-Spencer JM, Stehfest KM, (2009) Background document for *Lophelia pertusa* reefs. OSPAR Commission, 32 pp.

Hall-Spencer JM, White N, Gillespie E, Gillham K, Foggo A (2006) Impact of fish farms on maerl beds in strongly tidal areas. Mar Ecol Prog Ser 326:1-9

Halpern BS (2003) The impact of marine reserves: do reserves work and does reserve size matter? Ecol Appl 13:117-137

Halpern BS, Lester SE, McLeod KL (2010) Placing marine protected areas onto the ecosystem-based management seascape. Proc Natl Acad Sci: in press

Hanna SS (1996) Designing institutions for the environment. Environ Dev Econ 1:122-125

Hannah L (2008) Protected areas and climate change. Ann NY Acad Sci 1134:201-212

Heinz Centre, (2008) Strategies for managing the effects of climate change on wildlife and ecosystems. The Heinz Centre, 48 pp.

Hill C (1995) Linear strips of rain forest vegetation as potential dispersal corridors for rain forest insects. Conserv Biol 9:1559-1566

Holt TJ, Rees EI, Hawkins SJ, Seed R, (1998) Biogenic reefs (volume IX). An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. Scottish Association for Marine Science (UK Marine SACs Project), 170 pp.

Howell KL, Mowles SL, Foggo A (2010) Mounting evidence: near-slope seamounts are faunally indistinct from an adjacent bank. Mar Ecol: in press

Howson CM, Connor DW, Holt RHF, (1994) The Scottish sealochs - an account of surveys undertaken for the Marine Nature Conservation Review. Joint Nature Conservation Committee, JNCC Report, No. 164. [Marine Nature Conservation Report No. MNCR/SR/27] 212 pp.

Howson CM, Davies LM, (1991) Marine Nature Conservation Review, Surveys of Scottish sealochs. A towed video survey of Loch Fyne. Volume 1 - Report. Report to the Nature Conservancy Council from the University Marine Biological Station, Millport. 49 pp.

Hoyt E (2005) Marine Protected Areas for whales, dolphins and porpoises: A world handbook for cetacean habitat conservation. Earthscan, London

Hughes DJ, (1998) Sea pens and burrowing megafauna (vol. III): an overview of dynamics and sensitivity characteristics for conservation management of Marine SACs. Scottish Association of Marine Science (UK Marine SAC's Project), 105 pp.

Hughes DJ, Nickell TD, (2009) Recovering Scotland's Marine Environment. Report to Scottish Environment LINK. Scottish Association for Marine Science, Internal Report No. 262, 63 pp.

Husebø Å, Nøttestad L, Fosså JH, Furevik DM, Jørgensen SB (2002) Distribution and abundance of fish in deep-sea coral habitats. Hydrobiologia 471:91-99

Hussain SS, Winrow-Giffin A, Moran D, Robinson LA, Fofana A, Paramor OAL, Frid CLJ (2010) An *ex ante* ecological economic assessment of the benefits arising from marine protected areas designation in the UK. Ecol Econ 69:828-838

IUCN, UNEP, WWF (1980) World conservation strategy. Living resource conservation for sustainable development. IUCN, Switzerland

Jennings S, Kaiser MJ (1998) The effects of fishing on marine ecosystems. In: J.H.S. Blaxter AJS, Tyler PA (eds) Adv Mar Biol, 34. Academic Press, p 201-212, 212a, 213-266, 266a, 268-352

Jones NS (1951) The bottom fauna off the south of the Isle of Man. J Anim Ecol 20:132-144

Jones PJS (2008) Fishing industry and related perspectives on the issues raised by no-take marine protected area proposals. Mar Policy 32:749-758

Kaiser MJ, Clarke KR, Hinz H, Austen MCV, Somerfield PJ, Karakassis I (2006) Global analysis of response and recovery of benthic biota to fishing. Mar Ecol Prog Ser 311:1-14

Kelleher G (1999) Guidelines for Marine Protected Areas. International Union for Conservation of Nature, Gland, Switzerland

Keller BD, Gleason DF, McLeod E, Woodley CM, Airame S, Causey BD, Friedlander AM, Grober-Dunsmore R, Johnson JE, Miller SL, Steneck RS (2009) Climate change, coral reef ecosystems, and management options for Marine Protected Areas. Environ Manage 44:1069-1088

Kelly S, MacDiarmid AB (2003) Movement patterns of mature spiny lobsters, *Jasus edwardsii*, from a marine reserve. New Zeal J Mar Fresh 37:149-158

Kinnear JAM, Barkel PJ, Mojseiwicz WR, Chapman CJ, Holbrow AJ, Barnes C, Greathead CFF, (1996) Effects of Nephrops creels on the environment. Fisheries Research Services Report No. 2/96, 12 pp.

Koslow JA, Boehlert GW, Gordon JDM, Haedrich RL, Lorance P, Parin N (2000) Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES J Mar Sci 57:548-557

Koslow JA, Gowlett-Holmes K, Lowry JK, O'Hara T, Poore GCB, Williams A (2001) Seamount benthic macrofauna off southern Tasmania: community structure and impacts of trawling. Mar Ecol Prog Ser 213:111-125

Lester SE, Halpern BS, Grorud-Colvert K, Lubchenco J, Ruttenberg BI, Gaines SD, Warner SAR (2009) Biological effects within no-take marine reserves: a global synthesis. Mar Ecol Prog Ser 384:33-46

Lindahl O, Hart R, Hernroth B, Kollberg S, Loo L, Olrog, L., Rehnstam-Holm A (2005) Improving marine water quality by mussel farming: a profitable solution for Swedish society. Ambio 34:131–138

Lipcius RN, Stockhausen WT, Seitz RD, Geer PJ (2003) Spatial dynamics and value of a marine protected area and corridor for the blue crab spawning stock in Chesapeake Bay. Bull Mar Sci 72:453-469

Littler MM, Littler DS, Blair SM, Norris JN (1985) Deepest known plant life discovered on an uncharted seamount. Science 227:57-59

Magnussen JE, Pikitch EK, Clarke SC, Nicholson C, Hoelzel AR, Shivji MS (2007) Genetic tracking of basking shark products in international trade. Anim Conserv 10:199-207

Magorrian BH, Service M (1998) Analysis of underwater visual data to identify the impact of physical disturbance on horse mussel (*Modiolus modiolus*) beds. Mar Pollut Bull 36:354-359

Magorrian BH, Service M, Clarke W (1995) An accoustic bottom classification survey of Strangford Lough, Northern Ireland. J Mar Biol Assoc UK 75:987-992

Marine and Coastal Nature Conservation Unit, Fowler S, (2010) Background document for common skate *Dipturus batis*. OSPAR Commission, 19 pp.

Marine Scotland, (2010) A Strategy for marine nature conservation in Scotland. Draft. 27 pp.

McClain CR, Lundsten L, Ream M, Barry J, DeVogelaere A (2009) Endemicity, biogeography, composition, and community structure on a Northeast Pacific seamount. PLoS ONE 4:e4141

McLeod E, Salm R, Green A, Almany J (2009) Designing marine protected area networks to address the impacts of climate change. Front Ecol Environ 7:362-370

Mercer T, Howson CM, Moore JJ, (2007) Site Condition Monitoring: Loch Sunart marine SAC and SSSI. Scottish Natural Heritage, Commissioned Report No. 286 (ROAME No. R06AC701), 347 pp.

Minchin D, Duggan CB, King W (1987) Possible effects of organotins on scallop recruitment. Mar Pollut Bull 18:604-608

Moore CG, Saunders GR, Harries DB, Mair JM, C.R. B, Lyndon AR, (2006) The establishment of site condition monitoring of the subtidal reefs of Loch Creran Special Area of Conservation. Scottish Natural Heritage, Commissioned Report No. 151 (ROAME No. F02AA409), 50 pp.

Morato T, Clark MR (2007) Seamounts: Ecology, fisheries and conservation. In: Pitcher TJ, Morato T, Hart PJB, Clark MR, Haggan N, Santos RS (eds) Seamounts: ecology, fisheries and conservation. Blackwell Publishing, Oxford, p 170-188

Mudge SM, Salgado MA, East J (1993) Preliminary investigations into sunflower oil contamination following the wreck of the M.V. Kimya. Mar Pollut Bull 26:40-44

National MPA Center, (2008) Framework for the national system of Marine Protected Areas of the United States of America. National Marine Protected Areas Center, 92 pp.

National Research Council (2001) Marine Protected Areas: Tools for Sustaining Ocean Ecosystems. National Academy Press, Washington, D. C.

Norse EA, Crowder LB, Gjerde K, Hyrenbach D, Roberts CM, Safina C, Soulé ME (2005) Place-based ecosystem management in the open ocean. In: Norse EA, Crowder LB (eds) Marine conservation biology: The science of maintaining the sea's biodiversity. Island Press, Washington, D.C., p 302-327

Oracion EG, Miller ML, Christie P (2005) Marine protected areas for whom? Fisheries, tourism, and solidarity in a Philippine community. Ocean Coast Manage 48:393-410

OSPAR Commission (2003) Recommendation 2003/3 on a network of Marine Protected Areas. OSPAR Convention for the protection of the marine environment of the Northeast Atlantic. Meeting of the OSPAR Commission, 23–27 June 2003, Bremen. OSPAR 03/17/1-E, Annex 9, Ref. § A-4.44a

OSPAR Commission, (2008) Case reports for the OSPAR list of threatened and/or declining species and habitats. OSPAR Commission, 261 pp.

Pálsson G, Helgason A (1996) Property rights and practical knowledge: The Icelandic quota system. In: Crean K, Symes D (eds) Fisheries management in crisis. Fishing News Books, Cambridge, MA, p 45-60

Palumbi SR, (2002) Marine reserves: A tool for ecosystem management and conservation. Pew Oceans Commission, pp.

Pitcher TJ (2007) Preface. In: Pitcher TJ, Morato T, Hart PJB, Clark MR, Haggan N, Santos RS (eds) Seamounts: Ecology, fisheries and conservation. Blackwell Publishing, Oxford, p xvii

Pollnac R, Christie P, Cinner JE, Dalton T, Daw TM, Forrester GE, Graham NAJ, McClanahan TR (2010) Marine reserves as linked social–ecological systems. Proc Natl Acad Sci: in press

Poloczanska ES, Hughes DJ, Burrows MT (2004) Underwater television observations of *Serpula vermicularis* (L.) reefs and associated mobile fauna in Loch Creran, Scotland. Estuar Coast Shelf Sci 61:425-435

Reeves RR (2009) Proceedings of the First International Conference on Marine Mammal Protected Areas, March 30 - April 3, 2009. Maui, Hawai'i, USA, p 128

Reid JB, Evans PGH, Northridge SP (2003) Atlas of cetacean distribution in north-west European waters. Joint Nature Conservation Committee, Peterborough

Richer de Forges B, Koslow JA, Poore GCB (2000) Diversity and endemism of the benthic seamount fauna in the southwest Pacific. Nature 405:944-947

Roberts CM (2002a) Deep impact: the rising toll of fishing in the deep sea. Trends Ecol Evol 17:242-245

Roberts CM, Andelman S, Branch G, Bustamante RH, Castilla JC, Dugan J, Halpern B, Lafferty KD, Leslie H, Lubchenco J, McArdle DA, Possingham HP, Ruckelshaus M, Warner RR (2003) Ecological criteria for evaluating candidate sites for marine reserves. Ecol Appl 13:S199-S214

Roberts CM, Hawkins JP, (2000) Fully-protected marine reserves: a guide. WWF Endangered Seas Campaign. University of York, 132 pp.

Roberts CM, McClean CJ, Veron JEN, Hawkins JP, Allen GR, McAllister DE, Mittermeier CG, Schueler FW, Spalding M, Wells F, Vynne C, Werner TB (2002) Marine biodiversity hotspots and conservation priorities for tropical reefs. Science 295:1280-1284

Roberts D, Davies C, Mitchell A, Moore H, Picton B, Portig A, Preston J, Service M, Smyth D, Strong D, Vize S, (2004) Strangford Lough Ecological Change Investigation (SLECI). Report to Environment and Heritage Service by the Queen's University, Belfast. Work Package 3. Commercial Fishing Activity in Strangford Lough. 35 pp.

Roberts JM (2002b) The occurrence of the coral *Lophelia pertusa* and other conspicuous epifauna around an oil platform in the North Sea. Underwater Technol 25:83-92

Roberts JM, Davies AJ, Henry LA, Dodds LA, Duineveld GCA, Lavaleye MSS, Maier C, van Soest RWM, Bergman MJN, Hühnerbach V, Huvenne VAI, Sinclair DJ, Watmough T, Long D, Green SL, van Haren H (2009a) Mingulay reef complex: an interdisciplinary study of cold-water coral habitat, hydrography and biodiversity. Mar Ecol Prog Ser 397:139-151

Roberts JM, Wheeler A, Freiwald A, Cairns S (2009b) Cold-water corals: the biology and geology of deep-sea coral habitats. Cambridge University Press, Cambridge

Rogers AD (1999) The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. Int Rev Hydrobiol 84:315-406

Rogers AD, Baco A, Griffiths H, Hart T, Hall-Spencer JM (2007) Corals on seamounts. In: Pitcher TJ, Morato T, Hart PJB, Clark MR, Haggan N, Santos RS (eds) Seamounts: Ecology, fisheries and conservation. Blackwell Publishing, Oxford, p 141-169

Ross SW, Quattrini AM (2007) The fish fauna associated with deep coral banks off the southeastern United States. Deep Sea Res (I Oceanogr Res Pap) 54:975-1007

Rowden AA, Schlacher TA, Williams A, Clark MR, Stewart R, Althaus F, Bowden DA, Consalvey M, Robinson W, Dowdney J (2010) A test of the seamount oasis hypothesis: seamounts support higher epibenthic megafaunal biomass than adjacent slopes. Mar Ecol: in press

Salm R, Clark J, Siirila E (2000) Marine and Coastal Protected Areas – A Guide for Planners and Managers. IUCN Gland, Switzerland

Scottish Natural Heritage, (2006) Lochs Duich, Long and Alsh Reefs Special Area of Conservation. Advice under Regulation 33(2) of the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended). 10 pp.

Seed R (1993) Invertebrate predators and their role in structuring coastal and estuarine populations of filter feeding bivalves. In: Dame RF (ed) Bivalve filter feeders in estuarine and coastal ecosystem processes. Springer-Verlag, Berlin, p 149–196

Sims DW, Reid PC (2002) Congruent trends in long-term zooplankton decline in the north-east Atlantic and basking shark (*Cetorhinus maximus*) fishery catches off west Ireland. Fish Oceanogr 11:59-63

Smith IP, Low PJ, Moore PG (2006) Legal aspects of conserving native oysters in Scotland. Mar Pollut Bull 52:479-483

Sobel J (1996) Marine reserves: necessary tools for biodiversity conservation? Global Biodivers 6:8–18

Sobel JA, Craig D (2004) Marine reserves: a guide to science, design, and use. Island Press, Washington, D.C.

Speedie CD, Johnson LA, Witt MJ, (2009) Basking shark hotspots on the West Coast of Scotland: Key sites, threats and implications for conservation of the species. Commissioned Report No. 339. Scottish Natural Heritage, 59 pp.

Stocks KI, Hart PJB (2007) Biogeography and biodiversity of seamounts. In: Seamounts: Ecology, fisheries and conservation. Blackwell Publishing, Oxford, p 255-281

Thompson PM, Van Parijs S, Kovacs KM (2001) Local declines in the abundance of harbour seals: implications for the designation and monitoring of protected areas. Journal of Applied Ecology 38:117-125

Tullrot A, (2009) Background document for *Zostera* beds, seagrass beds. OSPAR Commission, 39 pp.

University Marine Biological Station Millport, (2007) Conservation of the Native Oyster *Ostrea edulis* in Scotland. Scottish Natural Heritage, Commissioned Report No. 251 (ROAME No. F02AA408), 186 pp.

Walker R, Craighead L (1997) Analyzing wildlife movement in Montana using GIS. Proceedings of the 1997 ESRI European user conference, Copenhagen, p 1–18

Watling L, Norse EA (1998) Disturbance of the seabed by mobile fishing gear: a comparison with forest clearcutting. Conserv Biol 12:1180-1197

Weible CM (2008) Caught in a maelstrom: Implementing California Marine Protected Areas. Coast Manage 36:350-373

Wheeler AJ, Bett BJ, Billett DSM, Masson DG, Mayor D (2004) The impact of demersal trawling on NE Atlantic deepwater coral habitats: the case of the Darwin Mounds, United Kingdom. In: Barnes P (ed) Benthic habitats and the effects of fishing, American Fisheries Society Symposium 41. American Fisheries Society, Bethesda, p 807-817

Widdows J, Donkin P, Evans SV (1987) Physiological responses of *Mytilus edulis* during chronic oil exposure and recovery. Mar Environ Res 23:15-32

Wilson RR, Kaufmann RS (1987) Seamount biota and biogeography. In: Keating BH, Fryer P, Batiza R, Boehlert GW (eds) Seamounts, islands, and atolls, Geophysical Monograph 43. American Geophysical Union, Washington, D.C., p 355-377

6 Appendices

Appendix 1. Classification of marine protected area benefits **(source: Angulo-Valdés & Hatcher (2010) (adapted from Dixon & Sherman 1990, Sobel 1996, Costanza et al. 1997, Bohnsack 1998, National Research Council 2001)).**

MPA benefits								
To humans					To nature			
Direct		Indirect/off site						
Fishery	Non-fishery benefits	Management benefits	Education/ Research benefits	Cultural benefits	Process benefits	Ecosystem benefits	Population benefits	Species benefits
Protect spawning stocks	Allow harvesting of renewable and non-renewable resources	Reduce use and user conflicts	Improve understanding of natural systems	Improve peace-of-mind	Allow for suitable nutrient cycles	Eliminate second order impacts	Protect natural population structure and functioning	Protect keystone and dominant species
Increase population fecundity	Expand non-consumptive recreation opportunities (SCUBA, ecotourism)	Reduce incidental and bycatch mortality	Provide educational opportunities	Enhance aesthetic experiences and opportunities	Protect from coastal erosion	Maximize ecosystem resilience	Protect genetic resources and diversity	Prevent loss of vulnerable species
Foster reproductive capacity	Enhance and diversify economic activities	Reduce variance in yields	Allow knowledge permanence of undisturbed sites	Foster constructive social activities	Provide physical refuge	Preserve natural communities composition and functioning	Restore population size and age structure	Sustain species presence and abundance
Provide undisturbed spawning sites	Increase wilderness opportunities	Maintain diversity of fishing opportunities.	Provide cumulative understanding from multiple studies at one site over time	Promote spiritual relations and development	Maintain global climate regulation	Ensure biodiversity protection	Protect spawning populations (commercial and non-commercial)	Prevent loss of rare species

MPA benefits								
To humans					To nature			
Direct		Indirect/off site						
Fishery benefits	**Non-fishery benefits**	**Management benefits**	**Education/ Research benefits**	**Cultural benefits**	**Process benefits**	**Ecosystem benefits**	**Population benefits**	**Species benefits**
Enhance eggs and larvae production	Broaden and strengthen economy	Improve management and efficiency.	Reduce risks to long-term experiments	Provide foundation to increase public awareness and compliance	Protect critical habitats	Maintain key areas (reproductive, nursery, feeding)	Allow recovery of depleted populations	Protect low-reproductive species
Provide export of egg and larvae	Enhance other forms of income generation	Insure against management failures.	Enhance synergy from cumulative studies	Promote concern for future generations.	Maintain biological diversity	Allow for ecosystem recovery	Increase reproductive outputs	Allow for complete species interaction
Build up fishery recruitment	Protect attractive habitats for tourism	Facilitate stakeholder involvement.	Provide long-term monitoring areas	Improve aesthetic values	Allow for the transformation, detoxification and sequestration of pollutants			Protect migratory species
Support sport trophy fisheries		Reduce possibility of irresponsible development	Maintain memory of natural ecosystems	Preserve and expand historical knowledge				Restore species abundance and biomass
Allow for spillover of adults and juveniles		Promote holistic approach to management	Provide sites for enhanced primary and adult education	Facilitate cultural resource management				Restore species diversity
Increase spawning stock biomass			Preserve archeological sites					

MPA benefits								
To humans					To nature			
Direct		Indirect/off site						
Fishery benefits	Non-fishery benefits	Management benefits	Education/ Research benefits	Cultural benefits	Process benefits	Ecosystem benefits	Population benefits	Species benefits
Enhance spawning density			Provide biological information from unfished populations					
Diminish fishery-related genetic impacts								

Appendix 2: Description of priority marine habitats, features and species

The priority marine features considered in this report are:

1. Tidally swept communities
2. Biogenic reefs
3. Seagrass beds
4. Native oyster beds
5. Burrowed deep muddy habitats
6. Seamounts
7. Mobile species

6.1 Description of tidally swept communities

Annex 3 of the Draft Guidelines mentioned above includes a number of habitats and biotopes that are found in tidally swept environments, and to maintain ecological coherence, these habitats have been grouped together in this report under this collective heading. These would include file or flame shell (*Limaria hians*) beds, which have the JNCC marine habitat code SS.SMx.IMx.Lim,[74] occurring in the shallow, inshore subtidal. This small bivalve mollusc lives buried beneath the sediment surface binding debris together with their byssal threads into ‘nests’ (Mercer et al. 2007), forming reef-like structures of up to 700 individuals m^2 (Hall-Spencer & Moore 2000a). *Limaria hians* beds are listed as a Priority Habitat in the UK Biodiversity Action Plan and the Scottish Biodiversity List (Hughes & Nickell 2009); Loch Sunart is an area where this habitat has been designated as an SAC in part because of these reef-forming beds.[75]

Another important tidally swept community is horse mussel (*Modiolus modiolus)* beds (see also Section 6.2 on Biogenic reefs). There are two separate habitats listed by the JNCC in this category: SS.SBR.SMus.ModCvar,[76] with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tideswept very sheltered circalittoral mixed substrata, and SS.SBR.SMus.ModT, with hydroids and red seaweeds on tide-swept

[74] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001565
[75] http://www.jncc.gov.uk/ProtectedSites/SACselection/sac.asp?EUcode=UK0019803
[76] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000641

circalittoral mixed substrata.[77] In this environment, *Modiolus modiolus* exists semi-infaunally, binding the habitat together with its byssal threads and supporting communities of up to several hundred species (Holt et al. 1998). Individual *M. modiolus* may live over 25 years, and will not mature sexually until 3-6 years old; it may be one of the reasons why recruitment is poor in this species. While *M. modiolus* beds exist in SACs such as Lochs Duich, Long and Ailsh, these are primarily on bedrock in weakly-tidal regions; as tidal communities they are present in Loch Creran SAC in the tidal Creagan Narrows (Moore et al. 2006), and are very numerous in Shetland and in the tidal narrows of Lochs Leven and Eil (Howson et al. 1994). Horse mussel beds are listed as a Priority Habitat in the UK Biodiversity Action Plan,[78] and listed on the OSPAR List of Threatened &/or Declining Species and Habitats.[79]

A third important community in tidally swept habitats is maerl (SS.SMp.Mrl). Maerl beds in this environment can consist of *Lithothamnion glaciale* in shallow, brackish water (SS.SMp.Mrl.Lgla),[80] *Lithothamnion corallioides* on muddy gravel (SS.SMp.Mrl.Lcor),[81] and *Phymatolithon calcareum* in clean gravel or coarse sand (SS.SMp.Mrl.Pcal).[82] These calcified red seaweeds (Rhodophyta) grow as unattached nodules or branching twig-like structures on the seabed (Birkett et al. 1998, Barbera et al. 2003), and due to their requirement for light for photosynthesis, maerl is found in relatively shallow (< 20 m) water depths. The lattice formed by the loosely-packed branches provides a habitat for a wide range of small invertebrates, and the resulting high biodiversity associated with maerl beds has led to them being classed as a Priority Habitat in the UK Biodiversity Action Plan[83] and the Scottish Biodiversity List. They are also listed on the OSPAR List of Threatened &/or Declining Species and Habitats (Hall-Spencer et al. 2010).

Tidal rapid habitats are listed as a Priority Habitat in the UK Biodiversity Action Plan.[84] While the JNCC Marine Nature Conservation Review[85] considers these

---

77 http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000657
78 http://www.ukbap.org.uk/ukplans.aspx?id=37
79 http://www.ospar.org/content/content.asp?menu=00120000000132_000000_000000
80 http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000696
81 http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000710
82 http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000734
83 http://www.ukbap.org.uk/UKPlans.aspx?ID=40
84 http://www.ukbap.org.uk/UKPlans.aspx?ID=39
85 http://www.jncc.gov.uk/ukbap/BAPHabitats55_Tide-swept Channels.doc

environments to be < 5 m deep, this habitat is given a much broader depth range in the BAP, and there is no restrictive depth maximum.

6.2 Description of biogenic reefs

Biogenic reefs can be defined as:

> "*Solid, massive structures which are created by accumulations of organisms, usually rising from the seabed, or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef building organism and its tubes or shells, or it may to some degree be composed of sediments, stones and shells bound together by the organisms*" (Holt et al. 1998).

The most important biogenic reef forming species in Scottish waters are the cold-water coral, *Lophelia pertusa*, the serpulid worm (*Serpula vermicularis*), horse mussels (*Modiolus modiolus*) and the common or blue mussel (*Mytilus edulis*).

6.2.1 *Lophelia pertusa*

Cold-water corals are widely distributed and found in many parts of the world's oceans. The Atlantic, Mediterranean, Indian and Pacific Oceans have all been found to contain cold-water corals. Much of the current research has been undertaken in the north-east Atlantic where the majority of cold-water coral reefs have been found; these are usually dominated by the deep-water scleractinian coral, *Lophelia pertusa*, the commonest reef-building cold-water coral; JNCC habitat code SS.SBR.Crl.Lop[86], classed as a Priority Habitat in the UK Biodiversity Action Plan[87] and listed on the OSPAR List of Threatened &/or Declining Species and Habitats (Hall-Spencer & Stehfest 2009).

The largest reef complex in the world, the Sula Ridge Complex, found off the Norwegian coast, is over 14 km long and extends up to 35 m from the sea bed. Closer to the United Kingdom there are many reefs along the continental shelf and offshore

[86] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000457
[87] http://www.ukbap.org.uk/ukplans.aspx?id=45

banks such as Rockall, the Porcupine Seabight and a newly mapped inshore Mingulay reef complex in the Sea of Hebrides. The latter is the only biogenic reef complex to date to be found in shallow depths (120-190 m) and within territorial waters (Roberts et al. 2009a). The only area to have received protection (see Section 6.6) is the Darwin Mounds, a series of sand mounds sometimes referred to as sand volcanoes, colonised by cold-water corals and singled-celled xenophyophores (Roberts et al. 2009b). They are located 185 km off northwest Scotland and extend over an area of approximately 100 km^2 in the northern Rockall Trough. Recently, *L. pertusa* was also discovered growing on the legs of some North Sea oil rigs (cf. Roberts 2002b, Gass & Roberts 2006).

Recruitment, growth rate and age structure data are limited but it is known that cold-water corals are extremely slow growing and long-lived. A 1.5 m high colony of *L. pertusa* may be up to 366 years of age (Breeze et al. 1997).

Cold-water coral reefs are synonymous with high biodiversity. The complex three dimensional reef structures (living coral, dead coral framework and coral rubble) can support many thousands of species, including some commercial fish species, providing shelter and enhanced rates of prey capture (Auster 2005, Roberts et al. 2009b). Costello et al. (2005) recorded fish observations from a compilation of video and still photographic studies of *L. pertusa* reefs in the North-East Atlantic and concluded that while reefs did not support distinct assemblages of fish, over 90% of fish species and 80% of individuals were associated with reef habitat. In contrast, Ross & Quattrini (2007) showed that several fish species demonstrated specificity to deep-reef habitats. Off the coast of Norway, fish catches (including commercial species) and individual fish size were larger in *Lophelia* habitats (Husebø et al. 2002). Furthermore, data demonstrate that some fish species use coral reefs as spawning or nursery grounds, e.g. Norwegian *Lophelia* reefs supported high densities of gravid deep-water redfish, *Sebastes viviparus* (Fosså et al. 2000).

Moreover, the polychate worm *Eunice norvegica*, forms a significant symbiosis with several reef-forming scleractinian corals including *Lophelia pertusa*, which calcifies over its parchment tubes adding strength to the coral skeleton and providing protection to the worm (Roberts et al. 2009b).

6.2.2 *Serpula vermicularis*

Serpulid reefs are formed by the calcareous tubes of the worm, *Serpula vermicularis*, JNCC habitat code SS.SBR.PoR.Ser.[88] They are classed as a Priority Habitat in the UK Biodiversity Action Plan.[89] The tubes are approximately 4-5 mm in diameter and up to 150 mm in length. The worms live for 2 to 5 years and reach sexual maturity at one year of age.[90] In most instances, the worms live in solitary tubes, attached to hard substrate. However, in some cases worms settling in close proximity grow intertwining tubes and gradually form clumps which can enlarge to form small reefs. Serpulid reefs are found in sheltered seas worldwide, with the exception of the poles. They favour enclosed bodies of water with limited water exchange, allowing retention of larvae, and probably a lack of competition for space (Holt et al. 1998). They are generally 'stand alone' structures which can reach 1 m in height and diameter (Moore et al. 2006).

In the UK the only known living serpulid reefs are found in Lochs Creran (Poloczanska et al. 2004) and Teacuis, Scotland (Dodd et al. 2009). Serpulid reef remains were identified in the Linne Mhuirich arm of Loch Sween. These are thought to have died out some time between 1982 and the mid-1990s (Hughes & Nickell 2009). The Loch Creran reefs are thought to be the best developed of their kind in the world and are currently recognised under the EC Habitats Directive as a Special Area of Conservation (SAC).[91] They are found in shallow water (6-10 m deep); siltation and low oxygen content limit downward distribution (Holt et al. 1998). Serpulid reefs are important biodiversity hotspots; they provide a haven for other marine wildlife and a hard substrate for colonising organisms, e.g. sponges, sea squirts, anemones, hydroids and seaweeds, and provide cracks and crevices in which mobile species such as brittle stars, squat lobsters, marine snails and various species of crab (both commercial and non-commercial) shelter and forage. Fish are common around

[88] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000645
[89] http://www.ukbap.org.uk/ukplans.aspx?id=43
[90] http://www.marlin.ac.uk/reproduction.php?speciesID=4340
[91] http://www.jncc.gov.uk/ProtectedSites/SACselection/sac.asp?EUCode=UK0030190

serpulid reefs and large shoals of juvenile cod have been reported to migrate to them at night (Poloczanska et al. 2004). In all, over 60 species have been found on a single reef (Holt et al. 1998); some, e.g. the tunicate *Pyura microcosmus*, are reportedly limited largely to this habitat (Holt et al. 1998).

6.2.3 *Modiolus modiolus*

Horse mussel (*Modiolus modiolus*) reefs are listed as two separate habitats by the JNCC: SS.SBR.SMus.ModCvar[92] and SS.SBR.SMus.ModT (see Section 6.1 on Tidally swept communities).[93] They are more complex than horse mussel beds and occur in two main physical forms: 1) Semi-infaunal reefs, which grade in density and thickness from continuous dense, raised reefs to scattered clumps. These occur on mixed or muddy sediments and in a variety of current regimes, between the shallow infralittoral and 50 m in depth. 2) More unusually, infaunal or gravel-embedded reef communities form consisting of mounds up to 1 m high. These usually form in strong tidal waters at moderate depths (15-40 m). Infaunal reefs have not been identified in UK waters. *Modiolus* reefs have a north-western distribution and although patchy can be extensive, covering many hectares. They are, however, not found in low salinity areas. They have been identified in Scottish SACs such as Lochs Duich, Long and Alsh, as tidal communities in Loch Creran SAC, the tidal Creagan Narrows (Moore et al. 2006), are very numerous in Shetland and in the tidal narrows of Lochs Leven and Eil (Howson et al. 1994).

6.2.4 *Mytilus edulis*

Common or Blue Mussel (*Mytilus edulis*) reefs are JNCC habitat listed as a littoral biogenic reefs: LS.LBR,[94] as important components of a number of Priority Habitats in the UK Biodiversity Action Plan,[95] and listed on the OSPAR List of Threatened &/or Declining Species and Habitats (OSPAR Commission 2008). Well developed *Mytilus edulis* reefs take the form of hummocks or ribbons of densely packed living and dead mussels approximately 30-50 cm thick, and are often very extensive. They

---

[92] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000641
[93] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000657
[94] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000198
[95] http://www.ukbap.org.uk

accumulate large amounts of 'mussel mud' (faeces, pseudofaeces and sediments). *Mytilus edulis* is tolerant of a wide range of environmental variables hence reefs are widespread. However, the best examples are found in large, shallow inlets and bays, especially estuarine areas, where there are mixed, firm sediments and string currents. The reefs form mainly in the mid and low intertidal but are found at depths of up to 10 m in some places. Reef populations can be long-lived but are generally only 2 - 3 years old, with rapid rates of growth and reproduction. Predation by fish, invertebrates and inter-tidal birds (e.g. eiders and oyster catchers) is generally high. Reef community diversity depends on age and stability but they often represent the only hard substrate communities over wide areas.

Biogenic reefs have important effects on their physical environment, as they:

- Stabilise substrates
- Provide hard substrate for attachment of sessile organisms
- Provide habitat heterogeneity (i.e. crevices, surfaces) for colonisation
- Provide food sources for other organisms (e.g. faeces, pseudofaeces, sediments and direct consumption of the reef-forming organism by birds and benthic predators); additionally
- Some species, e.g. *Mytilus edulis*, are also important as a fishery

6.3 Description of seagrass beds

Seagrasses, flowering marine plants, occur around the UK in beds in the intertidal or shallow subtidal. There are two main species involved, *Zostera noltii* and *Zostera marina,* which may be considered sometimes as separate species with *Zostera angustifolia*. *Zostera noltii* beds in littoral muddy sand (LS.LMp.LSgr.Znol)[96] and *Zostera marina/angustifolia* beds on lower shore or infralittoral clean or muddy sand (SS.SMp.SSgr.Zmar)[97] are the two main seagrass biotopes identified by the JNCC. Seagrass beds exist around Scottish coasts, but suffered severe loss from "wasting disease" caused by the fungus *Labyrinthula macrocystis* in the 1920s and 1930s (Davison & Hughes 1998). The subtidal seagrass beds are among the most productive of shallow marine ecosystems, supporting a huge diversity of species, both in the beds

[96] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000349
[97] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000234

themselves and by exporting detritus that other ecosystems benefit from. Seagrasses also play an important role in stabilizing coastal sediment (Davison & Hughes 1998).

Zostera marina beds are widely distributed along the west coast of Scotland and the Hebrides, Orkney and Shetland. *Zostera marina/angustifolia* beds are well developed in the Moray and Cromarty Firths, where *Zostera noltii* beds are also present. Seagrass beds are a Priority Habitat in the UK BAP[98] and are listed under the Habitats Directive under Annex 1 Mudflats and sandflats covered by water at low tide and Sandbanks slightly covered by seawater. *Zostera* beds are also listed on the OSPAR List of Threatened &/or Declining Species and Habitats (Tullrot 2009).

6.4 Description of native oyster beds

The native oyster (*Ostrea edulis*) is a bivalve mollusc that occurs in estuarine and shallow coastal habitats sheltered from wave action, with sediments ranging from mud to gravel. Oysters can form dense beds, with dead shells and living individuals forming reef-like structures. Once widely distributed around British coastal waters, extensive oyster beds are now found only in a small number of localities in the UK, mainly in southern England and western Ireland,[99] in no small measure due to over-exploitation and infestation from the protist *Bonamia* spp. (University Marine Biological Station Millport 2007). Now rare, native oyster beds are included in the UK Biodiversity Action Plan[100] and the Scottish Biodiversity List as a Priority Species, and listed on the OSPAR List of Threatened &/or Declining Species and Habitats (Haelters & Kerckhof 2009). The JNCC Marine Habitat classification code for this biotope is SS.SMx.IMx.Ost (*Ostrea edulis* beds on shallow sublittoral muddy mixed sediment).[101]

Native oysters now occur mainly in small, scattered populations fringing the west coast sea lochs, usually at low population density. The summary by UMBS Millport (2007) of existing data on the status of *O. edulis* in Scotland shows that the species appears to be completely extinct in some former localities, with populations in many other areas reduced to remnants. Only Loch Ryan in Galloway still supports oyster

[98] http://www.ukbap.org.uk/ukplans.aspx?id=35
[99] http://www.marlin.ac.uk/habitatsbasicinfo.php?habitatid=69&code=1997
[100] http://www/ukbap.org.uk/UKPlans.aspx?ID=495
[101] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000788

beds large enough to sustain commercial harvesting, although there are extant populations in Lochs Sween, na Keal, Ailort and around Skye. There are other locations in the UMBS Millport (2007) report that may warrant re-examination.

It now accepted that dense oyster beds can provide beneficial services to coastal ecosystems including filtration of suspended matter and enhanced nutrient cycling, creation of feeding habitat and refugia from predation for mobile animals, and provision of substratum for other sessile species (Lindahl et al. 2005, Coen et al. 2007, Ferreira et al. 2009).

6.5 Description of burrowed deep muddy habitats

Burrowed deep mud (in water depths > 20 m) habitats are, like the tidally swept habitats described in Section 6.1, a combination of several similar habitats that have been combined here for the sake of ecological coherence. These habitats include seapens *Funiculina quadrangularis* and burrowing megafauna in undisturbed circalittoral fine mud (SS.SMu.CFiMu.SpnMeg.Fun),[102] seapens and burrowing megafauna in circalittoral fine mud (SS.SMu.CFiMu.SpnMeg),[103] *Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud (SS.SMu.CFiMu.BlyrAchi)[104] and burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud (SS.SMu.CFiMu.MegMax).[105] These muddy habitats are typical of fjordic Scottish sea loch environments, are often well burrowed in oxygenated conditions by megafaunal crustaceans such as *Nephrops norvegicus*, *Calocaris macandreae* and *Callianassa subterranea* (Atkinson 1986), and are home to the large, slow growing seapens such as *Funiculina quadrangularis* mentioned above and *Pennatula phosphorea*, the rare anemone *Pachycerianthus multiplicatus* and the extremely rare sea squirt *Styela gelatinosa*.

Seapens are octocorals uniquely adapted to living in muddy habitats; *F. quadrangularis* can attain a height of over 1 m (Hughes 1998). Scottish distributions of seapens were reviewed by Greathead et al. (2007). The seapens and burrowing

[102] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001183
[103] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001218
[104] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000209
[105] http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001994

megafauna habitat were also the subject of a review (Hughes 1998), detailing the numerous species of fish, echiuran worms and echinoderms that are also important burrowers of these muddy environments.

In Scottish waters there are deep mud habitats contained within several SACs such as Lochs Maddy, Duich, Long and Alsh. Mud habitats in deep water are a Priority Habitat in the UK BAP.[106] *Funiculina quadrangularis* and *Styela gelatinosa* are Priority Species in the UK BAP.[107,108]

6.6 Description of seamounts

Seamounts are defined by OSPAR as undersea mountains of volcanic origin, with a crest that rises more than 1000 m above the surrounding seafloor (McClain et al. 2009, Howell et al. 2010). Up to a million may exist globally (Pitcher 2007) but very few have been well sampled (Rowden et al. 2010).

Seamounts may be geographically isolated but can be genetically linked (Roberts et al. 2009b). Seamounts rising from the ocean floor transcend pelagic depth zones and create their own benthic depth zonation. The ecosystems on steep seamount flanks and pinnacles are different from those on continental shelves at similar depths because they are bathed in water with lower sediment loads which allows photosynthesis to occur to deeper depths (Littler et al. 1985). They provide rare hard substrate at ocean depths typically dominated by fine muds (Roberts et al. 2002, Norse et al. 2005) and alter the surrounding water flow in ways that enhance local productivity (Norse et al. 2005). As a result, seamount communities are biodiversity 'hotspots'. Analysis of more than 5,000 sea-floor images revealed that the mean biomass of epibenthic megafauna species on 20 southwest Pacific seamounts with prevalent scleractinian corals was almost four times greater than on the adjacent continental slope at comparable depths (Rowden et al. 2010).

[106] http://www.ukbap.org.uk/ukplans.aspx?id=41
[107] http://www.ukbap.org.uk/UKPlans.aspx?ID=317
[108] http://www.ukbap.org.uk/UKPlans.aspx?ID=590

There is evidence that deep-water ecosystems, in particular seamounts, potentially support high levels of endemism. Stocks & Hart (2007) reviewed seamounts worldwide and found that an average of 20% and as many as 100% of the species inhabiting them were endemic. Other studies have also shown >30 % endemism (Richer de Forges et al. 2000). However, this does not hold true for the limited number of seamounts studied; McClain et al. (2009) found little support for endemism on the Davidson Seamount off the central Californian coast, concluding instead that a large percentage of species in the assemblages also occurred in adjacent continental margins and a large percentage were also cosmopolitan. Similarly, Howell et al. (2010) found little evidence of endemism on Rockall Trough seamounts.

Regardless of the degree of endemism there is a general agreement that seamounts function as oases where primary and secondary production are locally enhanced and retained, often by upwelling, nutrient-rich waters, which in turn support aggregating fish (Auster 2005, Morato & Clark 2007) and rich benthic communities (including cold-water corals such as *Lophelia pertusa* (Rogers et al. 2007) (see also Section 6.2.1). Even in the absence of upwelling, seamounts provide a combination of strong currents and structural complexity which allows resident fishes to both feed and take refuge from predators among the seamount structures. These fishes and other animals increase the seamount's filtering area, providing more food to benthic communities than might otherwise be present (Norse et al. 2005).

Deep sea sponge communities often centre upon offshore seamounts, e.g. in the Sea of the Hebrides (Roberts et al. 2009b). The abundance of demersal seamount life and distinctive oceanographic features attract highly migratory pelagic predators including cetaceans, seabirds, sharks, tunas and bill-fishes (see also Section 6.7 on Mobile species). They also act as a rendezvous for some epipelagic and deep sea fishes from a wider area to converge to mate or spawn, e.g. the orange roughy (Bull et al. 2001).

Demersal and pelagic seamount species that global fisheries target include pink and red precious gorgonian corals (*Corallium* spp.), black corals (*Antipathidae*), gold corals (*Gerardia* spp.), spiny lobsters (*Jasus* spp.), orange roughy (*Hoplostethus atlanticus*), hoki (*Macruronus novaezelandiae*), oreos (*Oreosomatidae*), pelagic amourhead (*Pseudopentaceros wheeleri*), rockfishes, wreakfish and hapuka

(*Polyprion* spp.), and Patagonian toothfish (Norse et al. 2005). Most of these are long-lived, late-maturing species, making them very vulnerable to overexploitation (Roberts 2002a). Pacific rockfishes can reach ages of up to 200 years (Cailliet et al. 2001), orange roughy >100 years, reaching maturity only at 22-40 years (Koslow et al. 2000), and black corals 1,800 years (Druffel et al. 1995). Some fishes are taken with longlines but many are targeted by trawls with associated collateral damage. Habitat-forming corals and sponges prevalent on seamounts are also long-lived and particularly vulnerable to physical trawl damage. Recovery can take years, decades or even centuries, if it is possible at all.

Seamounts are known to influence their physical environment downstream to a distance of at least twice their diameter (R. Turnewitsch, SAMS, pers. comm.). Seamounts also supply species to neighbouring shelf, slope or abyssal sediments (Norse et al. 2005, McClain et al. 2009). Furthermore, seamounts may act as stepping stones facilitating long-distance dispersal of species across oceans (Wilson & Kaufmann 1987), thus playing an important role in the connectivity of populations (Howell et al. 2010).

6.7 Description of mobile species

A coherent MPA network should include sites and critical habitats that are fundamental to the survival of mobile species such as seabirds, cetaceans, pinnipeds, fish and invertebrates. An MPA network cannot be ecologically coherent if mobile species and their critical habitats are not included.

Mobile species are key components of marine ecosystems and biodiversity worldwide. A number of nationally and internationally important mobile species reside in Scottish territorial waters.

6.7.1 Seabirds

Seabirds are important components of many marine ecosystems. Seabirds currently have legal protection whilst at their nests and SACs can be designated to protect a few species listed as rare and vulnerable on Annex I of the Birds Directive or regularly occurring migratory species.[109] However this means that important species that are either non-migratory, fall below the threshold for Natura 2000, or are not listed are overlooked. An ecologically coherent network of MPAs should take into account seabirds, their critical habitats, feeding/foraging and breeding areas and concentrations of non-breeding individuals (e.g. over-wintering populations).

An important Scottish species is the black guillemot (*Cepphus grylle*). This species is not listed as a Priority Species on the UK BAP but it does feature as an important component in a number of Priority Habitats.[110,111] The black guillemot is not considered migratory but nearly all of the UK and half of the EU population are found in Scottish waters (in particular around the Shetland and Orkney Islands) and should therefore be considered to form significant aggregations of national importance. The black guillemot is a benthic forager, preying on benthic fish, e.g. sandeels and blennies, and invertebrates, thus the protection of these critical benthic habitats is also essential for the species' survival, and that of other seabirds.

Information about the distribution of black guillemot and other important seabirds in Scotland was compiled by the census, Seabird 2000.[112]

6.7.2 Cetaceans

Cetaceans are warm-blooded, intelligent mammals that live their entire lives in the sea. They are *k*-selected, long-lived, have late maturation, reproduce slowly, invest heavily in the upbringing and development of each offspring and engage in complex social behaviour. In Scottish waters the following cetaceans (Table 6) are documented (Reid et al. 2003, Clark et al. 2010):

[109] http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm
[110] http://www.ukbap.org.uk
[111] http://www.ukbap.org.uk/ukplans.aspx?id=27
[112] http://www.jncc.gov.uk/page-3176

Table 6. Summary of cetaceans in Scottish waters.

Species	Common name	BAP code
Balaenoptera acutorostrata	Minke Whale	753[113]
Balaenoptera physalus	Fin Whale	753[15]
Delphinus delphis	Common Dolphin	337[114]
Eubalaena glacialis	Northern Right Whale	753[15]
Globicephala melas	Long-finned Pilot Whale	339[115]
Grampus griseus	Risso's Dolphin	337[16]
Hyperoodon ampullatus	Northern Bottlenose Whale	339[17]
Lagenorhynchus acutus	Atlantic White-sided Dolphin	337[16]
Lagenorhynchus albirostris	White-beaked Dolphin	337[16]
Megaptera novaeangliae	Humpback Whale	753[15]
Mesoplodon bidens	Sowerby's Beaked Whale	339[17]
Mesoplodon mirus	True's Beaked Whale	339[17]
Orcinus orca	Killer Whale	339[17]
Phocoena phocoena	Harbour Porpoise	514[116]
Physeter catodon	Sperm Whale	339[17]
Pseudorca crassidens	False Killer Whale	
Tursiops truncatus	Bottle-nosed Dolphin	337[16]
Ziphius cavirostris	Cuvier's Beaked Whale	339[17]

Scottish marine areas in which adequate data exists to identify significant populations that may benefit from spatial protection include (Clark et al. 2010):

The Hebrides

- The Inner Hebrides, the Minches and the Sea of the Hebrides - harbour porpoise
- North-east Isle of Lewis - Risso's dolphins
- The Inner Hebrides and the Sound of Barra - bottlenose dolphins

Other species present in the Hebrides that could benefit from protective measures include common dolphins, white-beaked dolphins, minke whales and killer whales.

[113] http://www.ukbap.org.uk/UKPlans.aspx?ID=753
[114] http://www.ukbap.org.uk/UKPlans.aspx?ID=337
[115] http://www.ukbap.org.uk/ukplans.aspx?ID=339
[116] http://www.ukbap.org.uk/ukplans.aspx?ID=514

North-east Scotland

- South coast, Outer Moray Firth - harbour porpoise
- Inner Moray Firth and north east Scottish coast to St. Andrew's Bay - bottlenose dolphins[117]
- South coast, Outer Moray Firth - minke whales
- Aberdeenshire coast - white-beaked dolphins

6.7.3 Pinnipeds

Pinnipeds, *viz*. grey seals (*Halichoerus grypus*) are among the rarest seals in the world: the UK population represents about 40% of the world population and 95% of the EU population.[118] 77% of the European Union's grey seal and 36% of the world's population resides in Scotland (Duncan & Boyd 2007). Several Scottish sites are already designated as SACs:

- Faray and Holm of Faray, Orkney Islands,[119] support the second largest breeding colony of grey seals in the UK, contributing around 9% of annual UK pup production.
- Isle of May,[120] Fife, supports the largest east coast breeding colony of grey seals in Scotland and the fourth-largest breeding colony in the UK, contributing approximately 4.5% of annual UK pup production.
- Monach Islands,[121] Western Isles, off the Outer Hebrides, hold the largest breeding colony in the UK, contributing over 20% of annual UK pup production.
- North Rona,[122] Western Isles supports the third-largest breeding colony in the UK, representing some 5% of annual UK pup production.
- Treshnish Isles,[123] Argyll and Bute, support a breeding colony of grey seals, contributing just under 3% of annual UK pup production.

The harbour or common seal (*Phoca vitulina*)[124] is also an important candidate for consideration, especially in light of declines documented in recent years (Thompson

[117] an SAC is already in place for part of this area
[118] http://www.jncc.gov.uk/protectedsites/sacselection/species.asp?featureintcode=s1364
[119] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0017096
[120] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0030172
[121] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0012694
[122] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0012696
[123] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0030289

et al. 2001). The UK population represents about 5% of the world population of *P. vitulina*, approximately 50% of the EU population, and 45% of the European subspecies. The European population has shown a marked recovery after being reduced by a viral epidemic in the late 1980s. The vast majority of common seal haul-outs are found on the coasts of Scotland. Several Scottish sites are already designated as SACs:

- Ascrib, Isay and Dunvegan, Highlands,[125] represents one of the larger discrete colonies of common seals in the UK, holding around 2% of the UK population.
- Dornoch Firth and Morrich More, Highlands,[126] support a significant proportion of the inner Moray Firth population of common seal. The seals, are the most northerly population to utilise sandbanks. Their numbers represent almost 2% of the UK population.
- Eileanan agus Sgeiran Lios mór**,** Argyll and Bute,[127] The island of Lismore is a composite site comprising five groups of small offshore islands and skerries which are extensively used as haul-out sites by the colony. Seal numbers represent just over 1% of the UK population.
- The Firth of Tay & Eden Estuary Angus,[128] haul-out supports ca. 600 adults, representing around 2% of the UK population of this species.
- Mousa, Shetland Islands,[129] supports one of the largest groups of common seal in Shetland and is one of the most northerly groups in the UK. The site supports just over 1% of the UK population.
- Sanday, Orkney Islands,[130] supports the largest group of common seal at any discrete site in Scotland. The breeding groups represent over 4% of the UK population. Nearshore kelp beds that surround Sanday are important foraging areas for the seals.
- South-East Islay Skerries, Argyll and Bute,[131] hold a nationally-important population. The south-east coastline areas are extensively used as pupping,

---

[124] http://www.jncc.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1365
[125] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0030230
[126] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0019806
[127] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0030182
[128] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0030311
[129] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0012711
[130] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0030069
[131] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0030067

moulting and haul-out sites by the seals, which represent between 1.5% and 2% of the UK population.

- Yell Sound Coast, Shetland Islands,[132] is the most northerly UK site and supports a colony representing over 1% of the UK

6.7.4 Fish

Fish (many of which are commercially important) should also be considered in MPA site selection and would benefit both directly and indirectly from MPA protection. Many examples exist in Scotland, two of which are discussed in detail here.

The common skate (*Raja batis*) is the largest European batoid fish. Females can reach lengths of 285 cm and males 205 cm. Males mature at a length of 125 cm (over 10 years old). Size and age at maturity for females is unknown. Longevity is estimated at 50 years. Mature females can only produce up to 40 large eggs (14-24 cm long) per year which are deposited in spring and summer. It is a demersal species, usually found in shallow coastal waters and shelf seas to 200 m, but occasionally down to 600 m. They hunt crustaceans and fish both in mid water and on the seabed. The common skate is listed as a Priority Species in the UK Biodiversity Action Plan.[133] It is also classified as Endangered on the IUCN Red List[134] and populations have declined dramatically in UK, Irish and Scottish waters as a result of targeted fishing and by-catch (e.g. Brander 1981, Hughes & Nickell 2009). Skates are also on the OSPAR List Of Threatened &/or Declining Species and Habitats (MCNCU & Fowler 2010).

The basking shark (*Cetorhinus maximus*) is the world's second largest fish, reaching up to 11 m in length and up to 7 tonnes. Basking sharks are found throughout Scottish waters but particular 'hotspots' were identified on the west coast: the Isles of Hyskeir and Canna, Sea of the Hebrides; the Isle of Coll, Inner Hebrides; and West Mull and the Treshnish Isles (Speedie et al. 2009). Basking sharks are long-lived and slow growing, reaching sexual maturity between 16 and 20 years of age. They have a gestation period of 1-3 years and produce litters of up to 6 pups on an irregular basis

[132] http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUcode=UK0012687
[133] http://www.ukbap.org.uk/UKPlans.aspx?ID=543
[134] http://www.iucnredlist.org/apps/redlist/details/39397/0

(Compagno 1984) and thus are vulnerable to exploitation or disturbance. The last Scottish basking shark fishery closed in the Clyde in 1994 and the species is currently protected within the 12 nautical mile limit of Scotland under the Wildlife and Countryside Act 1981[135] and has legal protection in England and Wales (Wildlife and Countryside Act 1981[28] and Countryside and Rights of Way Act 2000)[136] but the species is still exploited outside UK waters. The species is also a Priority Species in the UK BAP.[137] Internationally, basking sharks are on the OSPAR List of Threatened &/or Declining Species and Habitats (APECS & Curd 2009); the IUCN list basking shark as 'Vulnerable' globally and 'Endangered' in the north-east Atlantic due to over-exploitation.[138] They are also listed in Appendix II of the Convention on the International Trade in Endangered Species of Flora and Fauna (CITES).[139]

6.7.5 Other mobile species

MPA protection should not be restricted to the mobile species discussed above. Mobile invertebrates, such as the European spiny lobster (also known as crawfish, crayfish or rock lobster), *Palinurus elephas*[140] (as listed in Annex 3 of the draft MPA guidelines), would also benefit from MPA protection. The main UK populations of European spiny lobster are confined to the west coast of Scotland, the extreme south-west coasts of England & Wales and the west coast of Ireland. Studies in New Zealand have clearly demonstrated spiny lobster, *Jasus edwardsii*, recovery in marine reserves (Kelly et al. 2000): "linear models indicated that the mean density of the total lobster population increased 3.9 and 9.5% in shallow (<10 m depth) and deep sites (>10 m depth), respectively, for each year in which the reserves were established, while the mean size of lobsters was estimated to increase by 1.14 mm per year of protection. As a consequence lobster biomass (kg 500 m^{-2}) was conservatively estimated to increase by 5.4% per year of protection in shallow sites and 10.9% per year of protection in the deep sites, and egg production (eggs 500 m^{-2}) by 4.8 and 9.1% per year of protection for shallow and deep sites respectively." Such recovery

135 http://www.jncc.gov.uk/default.aspx?page=3614
136 http://www.hmso.gov.uk/acts/acts2000/20000037.htm
137 http://www.ukbap.org.uk/UKPlans.aspx?ID=203
138 http://www.iucnredlist.org/apps/redlist/details/4292/0
139 http://www.cites.org/eng/app/appendices.shtml
140 http://www.jncc.gov.uk/_speciespages/2482.pdf

has been shown to have positive effects on spiny lobster fisheries in areas adjacent to marine reserves around the world (cf. Kelly & MacDiarmid 2003, Goni et al. 2010).

Published by Scottish Environment LINK, 2011
2 Grosvenor House, Shore Road, PERTH PH2 8BD
http://www.scotlink.org

LINK is a Scottish Charity No SC000296 and a Scottish Company Limited by guarantee under Company No SC250899.

LINK is pleased to acknowledge the funding for this report, and associated work, from the Esmée Fairbairn Foundation and The Tubney Charitable Trust.