Pinnipeds, people, policy and practice: the implications of grey seal movements for the conservation and management of mobile marine species

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Abstract:	Grey seals (Halichoerus grypus) of the northeast Atlantic are protected at discrete locations designated as European Marine Sites (EMS) during their reproductive periods and in two Sites of Special Scientific Interest (SSSI). As a mobile marine species, grey seals then leave these sites to spend other aspects of their annual life cycle in non-designated habitat. There is limited information on individual grey seal movements and grey seal distribution in this region. Citizen science photo identification (PID) revealed the movements of 477 grey seals at a regional scale (n= 54 sites up to 230km apart) for over a decade. Movements highlighted two potential groupings with considerable individual variability. Four EMS were linked to a maximum of 18 sites and two SSSIs were linked to a maximum of 41 sites where grey seals have no protection. Observed seal movements support the value of enforcing existing SSSI legislation at both the well-connected West and North Cornwall sites and SSSIs across the region could be reviewed to extend the number of seal sites protected. The application of functional linkage from EMS and SSSIs could considerably increase conservation efforts. Ten Marine Conservation Zones (MCZs) were visited by grey seals from four EMS and two SSSIs so as a mobile species, grey seals could be included in MCZ management plans. This analysis has shown that there is considerable potential for increasing grey seal conservation within the existing marine protected area network of the Celtic Sea region for this UK special responsibility species.

Pinnipeds, people, policy and practice

Pinnipeds, people, policy and practice: the implications of grey seal movements for the conservation and management of mobile marine species

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ABSTRACT

Grey seals (Halichoerus grypus) of the northeast Atlantic are protected at discrete locations designated as European Marine Sites (EMS) during their reproductive periods and in two Sites of Special Scientific Interest (SSSI). As a mobile marine species, grey seals then leave these sites to spend other aspects of their annual life cycle in non-designated habitat. There is limited information on individual grey seal movements and grey seal distribution in the southwest UK. Citizen science photo identification (PID) revealed the movements of 477 grey seals at a regional scale (n= 54 sites up to 230km apart) for over a decade. Movements highlighted two potential groupings with considerable individual variability. Four EMS were linked to a maximum of 18 sites and two SSSIs were linked to a maximum of 41 sites where grey seals have no protection. Observed seal movements support the value of enforcing existing SSSI legislation at both the well-connected West and North Cornwall sites and SSSIs across the region could be reviewed to extend the number of seal sites protected. The application of functional linkage from EMS and SSSIs could considerably increase conservation efforts. Twelve Marine Conservation Zones (MCZs) were visited by grey seals from four EMS and two SSSIs so as a mobile species, grey seals could be included in MCZ management plans. This analysis has shown that there is considerable potential for increasing grey seal conservation within the existing marine protected area network of the Celtic Sea region for this UK special responsibility species.

Keywords: grey seals, mobile marine species, Marine Protected Areas, photo ID, citizen science, marine management.

INTRODUCTION

Grey seals (*Halichoerus grypus*) are a carnivorous pinniped that inhabit continental shelf regions of the North Atlantic Ocean. Their global population is estimated to be 632,000 animals including 316,000 mature individuals with two genetically distinct groups in the northwest Atlantic with 250,000 adults and the northeast Atlantic with 66,000 adults (Lowry *et al*., 2017).

Grey seals are a mobile marine species, spending more than 80% of their time at sea and 90% of that below the surface (Harrison *et al*., 2006). Despite their mobility, they also demonstrate site fidelity visiting the same predictable seasonal terrestrial sites to haul out and reproduce (Gerondeau *et al*., 2007). These are connected to offshore foraging areas up to 100 km away accessed along prominent corridors (Jones *et al*., 2015).

The movements and distribution of grey seals have been studied using a variety of techniques including tags, brands, paint dye, photogrammetry and satellite telemetry (Walker, 2011). Telemetry studies have revealed that adult grey seals can make repeated journeys of hundreds of kilometres between haul out and foraging sites (McConnell *et al*., 1992; McConnell *et al*., 1999; Vincent *et al*., 2005), covering as much as 75 to 100 km per day (McConnell *et al*., 1999). While these studies provide detailed information on movements and foraging behaviour at the individual level, the large scale application of this technology is limited by high costs (Karlsson *et al*., 2005). Satellite tag deployment durations typically last a few months and end during the grey seal annual moult when transmitters glued to their fur are shed (Sharples *et al*., 2012). Capture and attachment procedures can be invasive, may cause disturbance at haulout sites and can have hydrodynamic costs for tagged individuals (Hazekamp *et al*., 2009).

Photo identification (PID) is an effective (Beck *et al*., 2014; Kaufman *et al*., 2011; Wursig & Jefferson, 1990) and minimally invasive research technique (Karlsson *et al*., 2005; Hiby *et al*., 2007; Marshall & Bennett, 2010) resulting in limited or no disturbance to the target species (Thompson & Wheeler 2008; Wursig & Jefferson 1990). PID can generate a range of information, including insights into distribution, abundance, habitat use, movements, life history and behaviour (Macleod *et al*., 2010). If undertaken as part of long-term structured research programme, the approach can allow longitudinal studies of individuals over a lifetime of reproductive output, aid an assessment of cumulative threats and provide insights into individual behaviour (Macleod *et al*., 2010). PID has been used on a range of marine species in the northeast Atlantic to track long term movements and residency behaviour for bottlenose dolphins (*Tursiops truncatus)* (O' Brien *et al*, 2009); killer whales (*Orcinus orca)* (Beck *et al*., 2014) as well as grey seals in the Baltic Sea (Karlsson *et al*., 2005), Ireland, Wales (Kiely *et al*., 2000; Boyle, 2011) and France (Gerondeau *et al*., 2007).

Grey seals are ideal candidates for PID as they are long lived, relatively large and can be individually identified using natural fur patterns and scars (Wursig & Jefferson, 1990). Unique fur patterns remain

legible and stable throughout their lives (Figure 1); particularly for adult and juvenile female grey seals (Paterson *et al*., 2013). The darkening of the adult male fur, combined with scarring from fighting with conspecifics, may however reduce the chances of re-identifying individuals (Paterson *et al*., 2013).

The United Kingdom (UK) hosts 38% to 44% of the world's grey seal population on the basis of pup production (SMRU, 2014) and as such has a key role to play in the conservation of the species (Beaumont & Goold, 2007). In the UK, grey seals in Scotland may be geographically isolated from those in the Celtic Sea region, (Walton *et al*., 1997) however long-range movements between these areas have been observed (Vincent *et al*., 2017). In the Celtic Sea (which includes Cornwall, Devon, Wales, France and Ireland) short term movements of grey seals have been recorded between locations in the east and southeast coast of Ireland and southwest Wales (Kiely *et al*., 2000), north and southwest Wales (SMRU, 2013) and between France and the Isles of Scilly, Cornwall, Wales and the Channel Isles (Huon *et al*., 2015; Vincent *et al*. 2005).

Grey seals are protected by the Bern Convention 1979 (IUCN Red List of Threatened Species, Annex III) as a vulnerable migratory species that constitutes a natural heritage asset to be preserved for future generations. Protection in European waters is delivered through the European Union Habitats Directive 1992 (Annex II and V), which requires European Marine Sites (EMS) to be established to protect their breeding habitat (Rees *et al*., 2013). In the UK, the Department for the Environment, Food and Rural Affairs is establishing a network of designated Marine Conservation Zones (MCZs) and has begun addressing the needs of mobile marine species within the process, however grey seals have yet to be considered under this framework (JNCC, 2016b; Wildlife Trusts, 2015). Terrestrial protection for grey seals exists in the UK in the form of Sites of Special Scientific Interest (SSSI) which incorporate intertidal haul out habitat above the mean low water mark. Where listed in the SSSI citation, it is an offence to damage, disturb or destroy seals (JNCC, 1989).

In the UK, seals are also offered protection by national legislation under the Seal Conservation Act (1970) and via EMS designation. In the Celtic Sea, there are five EMS reflecting the UK's special responsibility to protect this species (JNCC, 2016) including one site specifically for grey seals (Pembrokeshire Marine; in Wales; Figure 2) and four sites where grey seals are a qualifying feature – two in Wales (Llyn Peninsula not shown on map and Cardigan Bay; Figure 2) and two in southwest England (Lundy and the Isles of Scilly; Figure 2). EMS for grey seals in the UK include the largest breeding colonies and ensure coverage of the geographical range of the species (JNCC n.d.). A further EMS offers protection to grey seals in northwest France (Parc Naturel Marin d'Iroise; Figure 2). However, the challenge for mobile species management is that conservation success can depend on the condition of sites outside of protected areas (Runge *et al*., 2014).

Given the location of the UK's southwest peninsula (Figure 2), Cornwall has the potential to act as a geographical hub for the Celtic Sea grey seal population. A more coherent understanding of long term grey

seal movements across the region will likely be critical to inform ongoing conservation efforts (Marshall & Bennett, 2010). Species with predictable linkages (connectivity) between known areas can be vulnerable to habitat loss and the magnitude of threats elsewhere can influence the success of conservation measures within EMS (Runge *et al*., 2014).

Public involvement in science programmes can yield considerable benefits relative to the resources committed (Prince, 1993; Witt *et al*., 2007). The digital age has created revolutionary tools for PID from photography and image manipulation, email and social media to mobile recording applications and online data management platforms enabling organisations to engage and interact with large numbers of people (Davis *et al*., 2012; Zenetos *et al*., 2013; Gemmell *et al*., 2015).

Amateur naturalists are keen to engage with the environment and wildlife (Silvertown, 2009; Davies *et al*., 2011) and they have provided an opportunity to improve knowledge on the distribution, movements and welfare status of grey seals in southwest UK. This is particularly important given reported levels of fisheries impact on seals (Allen *et al*., 2012; Northridge *et al*., 2014; Northridge *et al*., 2016) and increasing interests in the development of marine spatial planning for UK and European waters. Furthermore, wide scale survey efforts will likely increase opportunities to more coherently document the potential for connectivity between coastal regions and EMS. Insights into connectivity will be key to securing positive population trajectories, as events distant from EMS may influence their success. This study provides novel insight into the connectivity of designated EMS, MCZs and SSSIs with multiple non-designated sites linked by grey seals across the Celtic sea.

MATERIALS AND METHODS

In 2000, Cornwall Seal Group Research Trust (CSGRT) began a long-term research programme to construct a comprehensive PID catalogue of grey seals at the West Cornwall site, one of only two key mainland haul out sites in southwest England - the other being at North Cornwall (Leeney *et al*., 2010) (Figure 2). CSGRT's PID catalogue now includes data from 54 standardised sites (grouped by proximity) in southwest UK (40 in Cornwall, one in the Isles of Scilly, nine in Devon, three in Wales and one for Dorset). Catalogues have also been developed by the RSPB (Ramsey Island), The Wildlife Trust of South and West Wales (Skomer Island) in the Pembrokeshire Marine EMS, The Landmark Trust (Lundy Island) and Dorset Wildlife Trust (Figure 2).

Photographs of grey seals were taken during systematic, boat-based, coastal transect surveys (12 times a year) and from cliff top, land based surveys by volunteers, Non-Governmental Organisations (Coastwatch, Cornwall Wildlife Trust, National Trust and RSPB), local marine conservation groups and commerical marine ecotour operators covering a total of 54 standardised sites across the region. PID events were variable through time and space, with some contributors providing frequent and repeated photographs at specific locations (daily to once a month), while others were more sporadic. Context photos (zoomed out to show location) were taken of all seals to enable office based verification of data, then photographs were taken of individual seals from a variety of angles for PID, as permitted by the coastal geography.

All photographs were subject to quality control; ascertaining presence of meta data, including location, date and photo quality. PID survey albums and photographs were stored in digital archives as independent data collection events (by date, location and surveyor). The PID catalogue included representative photos of individual seals alongside descriptions of dominant fur patterns (on different regions of each animal, from both sides, from a variety of viewing angles and under a range of conditions for example when wet and dry or moulting).

Confirmed identifications of seals in the catalogue occurred when at least five fur patterns could be matched in the same relative positions (e.g. Figure 1) by the same project PID coordinator and moderated by at least one other surveyor trained and experienced in PID. A PID was rejected if either party was in doubt (e.g. five pattern matches but the rest of seal inconsistent or masked by substrate). Where seals were not immediately recognised by eye, the catalogue was searched using key word descriptions of visible fur pattern shapes. Seals that remained unidentified were added to the PID catalogue as new seals enabling future matching. Observation dates, locations, unique PID codes and supporting data were entered into a sightings database.

For the purposes of this paper, seals identifed at multiple sites were termed shared seals, and were plotted in a matrix of sites against sites (Kiely *et al*. 2000). This was translated into tables of nodes and edges (across 54 standardised sites) for import into Gephi (Bastian *et al*., 2009), an interactive visualisation and exploration platform for network analysis. Gephi sorts sightings into groups based on a user defined

modularity score. Modularity is a measure of connectivity between sites where more edges (a link between two sites) exist within a community than could be expected from a random model of movements. Resulting edge site links were mapped in ArcMap (ESRI, Redmond, USA). Differences in the number of sites visited by males and females were tested (Mann Whitney) within the statistical package R (R Core Team, 2014) and individual seal movement maps were created. Sites at which seals were identified were spatially cross-referenced to existing protected areas (i.e. EMS, MCZs and SSSIs) (Figures 3, 4 and 5).

RESULTS

Pinnipeds: seal movements

A total of 477 shared seals were identified across multiple sites up to 230 km apart (Figure 3). The majority of these resighted grey seals were identified at two sites (n=346); whilst seals were also seen at three sites (n=87); four sites (n= 33), five sites (n=8), six sites (n = 2) and seven sites (n=1). Shared seals created 1144 geographic linkages between the 54 PID sites at which seals were identified – of these, 16 sites were visited by ten or more shared seals over the study period (Table 1). Each of these 16 sites was linked with between five and 41 other locations. All seals identified at more than one site were assigned sex (54% female; 46% male). Seven seals first identified in 2000 were resighted in 2015 and 2016 of which four were males. Thirteen seals (ten males and three females) were identified as having died based on database matches made of dead seals photographed by Cornwall Wildlife Trust's Marine Strandings Network.

Four EMS in the region (Pembrokeshire, Lundy, Isles of Scilly and Iroise PNMI) were visited by 104 shared seals (66 females and 38 males) linking these EMS to a total of 26 different non-designated sites (Table 2). Seals visited 12 MCZs (Figure 5) and two SSSIs, the latter have grey seals included in their site citations – West and North Cornwall (Figure 2).

The most connected West Cornwall site (linked to 41 other sites including all four EMS by 379 shared seals) was studied for the longest duration (16 years). The other major haul out site in southwest England at North Cornwall (Leeney *et al*., 2010) was linked by 70 shared seals to 18 other sites including three EMS (Isles of Scilly, Lundy and Pembrokeshire Marine). Shared seals from the longest studied West Cornwall site travelled up to 180 km north to Ramsey Island in Wales, 110 km northeast to Morte Point in north Devon, 190 km southeast to Start Point in south Devon and 230 km south to the Iroise PNMI in northwest France (Figure 3).

An interconnectivity analysis of sites using Gephi suggested that with a modularity of one, three groupings may exist within the shared seal movements across southwest England – north coast, south coast and Mounts Bay (Figure 3).

Both male and female seals moved between EMS and non-designated sites, but only male seals visited all four EMS (Figure 4). The number of sites visited by female and male seals signficantly differed (Mann Whitney; p=0.0477) with females visiting more sites (mean 2.4; s.d. 1 site) than males (mean 2.3; s.d. 1 site). Fourty four shared seals visited four or more sites; of which 66% (n=29) were females. Female seals demonstrated greater spatial variation in their movements across a larger number of non-designated sites (e.g. Figure. 6 A to C).

Ranging distance for individual seals varied (Figure 6 A to C and D to F) as some showed consistent, seasonally repeated journeys to the same locations over time (Figure 6 C, D and E) whilst others demonstrated more variable patterns of movement (Figure 6 A).

People

Public engagement with CSGRT grew from 224 database contributions in 2008 to 3,338 in 2014, resulting in 19,579 database entries (n=16 years). Photographs were submitted from 54 standardised sites (between 2004 and 2015) ranging from southwest Wales (most northerly record) to northern Brittany, France (most southerly record). Reports originated from 154 members of the public, ranging from ad hoc single sightings to repeat surveyors following standardised protocols and from 18 additional organisations, 11 commercial marine ecotour operators, 28 contacts via social media websites and from seven systematic seal, boat-based PID projects.

Sixteen participants became long-term citizen scientists contributing photographs to the PID catalogue. Fourteen participants shared data for at least three years becoming PID mentors in their respective areas thereby providing a local focus for seal PID, advocacy and engaging the public in marine conservation efforts.

DISCUSSION

Data contributed by citizen scientists have provided greater insights into the movements of male and female grey seals, over a regional scale for longer time periods than possible through satellite tagging (Jones *et al*., 2013; Walker, 2011) and at a lower comparative cost (Macleod *et al*., 2010). It has also provided information on relative seal abundance, seasonal site occupancy and led to greater numbers of people engaging with nature. PID, utilising manual matching of fur patterns facilitated by key word searching, led to a knowledgebase of individual seal movements from a previously unreported network of seal sites across Cornwall, the Isles of Scilly, Devon and beyond. Although PID effort at EMS was the most variable, sporadic and opportunistic, results highlight the dependency of EMS on multiple non-designated seal sites.

Pinnipeds

Many PID projects have focussed on female grey seals (e.g. Hiby *et al*., 2007; Karlsson *et al*., 2005; Paterson *et al*., 2013) due to their distinctive patternation. Male grey seals have fur patterns with fewer, simpler markings, by comparison females have more complex fur patterns (Paterson *et al*., 2013; Vincent *et al*., 2001) providing contrasting challenges for manual key word PID. Over two thirds of grey seals in Cornwall are male (Leeney *et al*., 2010; Sayer, 2013, 2016). With slightly more female shared seals being re-identified than males, it was likely that females were proportionally over identified.

PID has enhanced understanding of the movements and site fidelity of individual seals to particular sites (Kiely *et al*., 2000; Macleod *et al*., 2010). In southwest England the maximum distances travelled by seals of 110 to 230 km were within limits recorded in other parts of their range (125 to 365 km in northeast Scotland) (Thompson *et al*., 1996).

Of the three shared seal groupings identified by network analysis, the concept of a proposed north and south coast network overlapping at the West Cornwall site is plausible and requires future investigation. It is possible that the Mounts Bay group may be an artefact arising from a small sample size.

Seal PID has demonstrated considerable variation between individual animals from seasonally and locationally repeated patterns to more variable movements. Seal movements were complex, combining elements of both site fidelity (Kiely *et al*., 2000) and migration (Jones *et al*., 2013). It seems plausible that there are dominant movement patterns adopted by grey seals based on age, sex, reproductive state and season, however the considerable degree of individuality observed in movement patterns (Figure 6) highlights the challenge faced by policy makers and managers seeking to ensure sustainable populations given the protected status of the grey seal.

Variable survey effort (from once a month to daily) suggests opportunities to identify individuals were likely missed and as such resulting patterns should be interpreted with caution and will in part reflect surveyor behaviour. As the chance of an identification and probability of a resighting were not equal at all sites, mark recapture techniques could not be robustly used for estimating abundance from PID (Gerondeau *et al*., 2007). Further, the technique does not allow complete reconstruction of movements made by seals. A priority for future PID research requires an integrated international approach with the amalgamation of different identification and recording systems especially focused on EMS.

People – individuals to society

Natural history citizen science projects champion public involvement, and participation in such schemes has expanded in recent decades (Bonney *et al*., 2009; Silvertown, 2009). These schemes recognise the need to directly engage society to improve the evidence base on which policy holders can make management decisions, largely with the drive towards more environmentally sustainable futures within budgetary contraints (Davies *et al*., 2011). These programmes can also improve local community based environmental awareness and the health and wellbeing of participants (Van Willigen, 2000; Koss & Kingsley, 2010). However, data from theses schemes could be used for aims far removed from the motivations of the volunteers who collected it. Engagment must be carefully managed alongside expectations for the future use of gathered datasets for fear of alieniating and disengaging participants (Ellis & Waterton, 2004).

The creation of a PID network has built community scientific capacity and expertise - an important socioeconomic outcome of any project (Shirk *et al*., 2012) supported by local marine conservation groups in collaboration with scientific establishments. Deeper public engagement through the use of PID informs local evidence based conservation and wins hearts and minds through direct personal association of individual people with individual seals.

On a wider scale, networks of active citizen scientists can add to the evidence base required to support the regional council's aspirational, strategic policy of 'environmental growth', itself an acknowledgement that the region's financial economy is underpinned by the leisure, recreation and tourism use of the marine and coastal environment (Cornwall Council, 2017).

Ultimately novel evidence about the interconnectivity of seal sites at a regional scale has made a valuable contribution to informing the effective conservation of grey seals for wider society.

Implications for conservation policy and management

EMS are the accepted method adopted by statutory conservation authorities for the conservation of grey seals in Europe. As a mobile marine species, grey seals do not remain within the limits of EMS boundaries

and reported seal movements reveal links from four EMS to non-designated habitat where additional wider measures may be required to support the effective conservation of the species (JNCC n.d.). The current selection of marine mammal protection areas focus on breeding criteria and only occcasionally acknowledge foraging or migration habitats (Hooker & Gerber, 2004). Most EMS are used in multiple ways by people and managed with a narrow set of habitats or species specific conservation objectives, but with no specific focus on the ecological function of the site (Rees *et al*., 2013). As EMS are designated for grey seal breeding habitat, the greater movement between and greater spatial interconnectivity of sites by individual females may have important implications. The application of the EU Habitat Directive's concepts of 'functional linkage' and 'site integrity' will be vital for the effective conservation of grey seals at this southern end of their range (Rees *et al*., 2013).

More recent marine designations exist in England in the form of Marine Conservation Zones (MCZs). Shared seals were identified within 12 MCZs (Figure 5). Management regimes for these MCZs could benefit seals by potentially focusing on: the control of marine based activity to reduce haul out disturbance; interventions to reduce fisheries bycatch; ghost fishing gear removal, reuse and recycling schemes to minimise the potential for entanglement – three key impacts of human activity on seals (Allen *et al*., 2012; Northridge *et al*., 2014; Sayer, 2015; Wilson, 2005). Additional measures could include: the application of anthropogenic noise emission thresholds, as considered by the EU Marine Strategy Framework (descriptor 11); control of fisheries effort to reduce prey displacement and depletion; and the holistic assessment of human activities that might cumulatively impact grey seals. Such approaches would likely increase the protection of grey seals at sites distant to current EMS, yet where seals spend a large proportion of their time. Whilst these measures are informed by a specific species they progress management towards an ecosystem based approach (Arkema *et al*., 2006).

For grey seals, terrestrial moulting sites in southwest England are identifiable from their relatively high connectivity weighting of site links (Table 1). Shared seals visiting the West Cornwall and North Cornwall seal sites fall within the Godrevy to St Agnes, and Boscastle to Widemouth SSSIs respectively where grey seals are included within both citations. The application and enforcement of SSSI legislation for disturbance would enhance the level of protection for grey seals at these sites with associated benefits for the favourable conservation status of all linked EMS.

Movement patterns revealed by this study suggest that conservation objectives will need to be extended to reflect the connectivity of sites for all parts of the grey seal annual life cycle. For example, currently designated pupping sites will need to be supported by protecting foraging sites and moulting sites (not currently designated) and corridor habitat potentially linking all three to create an ecologically coherent network for grey seals. The complex drivers and mechanisms involved in seal movements require considerably more study (Hays et al., 2016) but ensuring that protection follows grey seals as they move

around the Celtic Sea and at the sites they inhabit is currently achieveable through the application of functional linkage to EMS and SSSIs.

Seals from the Isles of Scilly, Cornwall and Devon move across national and international borders and this behaviour has important implications for Marine Spatial Planning activities which aim to deliver ecosystem based management. The planning activities across the regional sea scape (England, Wales, Ireland and France) will need to be integrated with management systems to ensure all important biological and ecological areas for grey seals are identified covering all stages of their life history if Marine Spatial Planning is to be effective for this species (Ehler & Douvere, 2009).

In a complex adaptive ecosystem, multiple impacts at the micro level can lead to unpredictable transformations at the macro level (Curtin & Prellezo, 2010). The effect of of eliminating non-designated seal sites (due to anthropogenic activities) from the wider scale network is unknown. What is more certain is that the favourable conservation status of Celtic Sea EMS is at least partly dependent on what happens to its shared seals when they are outside the EMS boundaries in currently undesignated habitat.

This study highlights that an integrated network of linked designated and non designated sites provide essential functional services for grey seals and so the site integrity and favourable conservation status of the EMS is dependent on many non-designated sites. This analysis of designated marine habitat management and grey seal sites reveals that there is considerable potential for increasing protection for this species using the existing Celtic Sea marine protected area network.

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FIGURES AND TABLES

Figure 1. Example pelage patterns from two long-term photo-identified seals – A male grey seal 'Hook' identified 210 times at three sites observed from both left and right-hand sides of the animal in 2000 and 2016 respectively and B female grey seal 'Carousel' identified 130 times at four sites observed from both left and right-hand sides of the animal in 2000 and 2016. Examples of key pelage patterns are highlighted.

Figure 2. Two major seal ID sites and European Marine Sites (EMS) in SW Wales, SW England and NW France designated for seals.

Figure 3. All shared seal PID connections between sites in the southwest UK.

Figure 4. Female and male grey seal links between EMS and non designated sites across southwest England.

Figure 5. All shared seal sites and marine protected areas.

Figure 6. Maps showing individual seal movements as reconstructed by PID. Arrows indicate inferred movements between sites. Star indicates location of site where pupping was observed.

Table 1. Most connected sites.

Table 2. Links between European Marine Sites established by the European Union Habitats Directive.

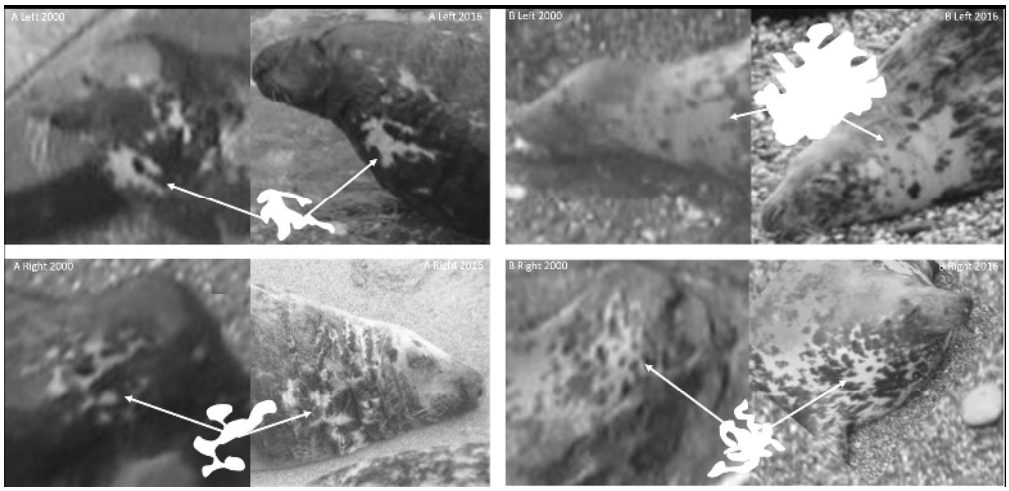

Figure 1. Example pelage patterns from two long-term photo-identified seals – A male grey seal 'Hook' identified 210 times at three sites observed from both left and right-hand sides of the animal in 2000 and 2016 respectively and B female grey seal 'Carousel' identified 130 times at four sites observed from both left and right-hand sides of the animal in 2000 and 2016. Examples of key pelage patterns are highlighted.

525x252mm (96 x 96 DPI)

Table 1. Most connected sites.

Site	Number of connecting sites	Total shared seals	Number of linked EMS
West Cornwall	41	379	4
West Penwith North	19	111	3
North Cornwall	18	70	3
Porthtowan	15	68	3
Pentire	16	63	3
Pembrokeshire (Skomer + Ramsey)	18+2	48	1
Roseland	16	47	1
Isles of Scilly	15	41	1
Hudder Down	16	40	2
St Austell Bay	13	35	2
Lizard	5	34	2
North Devon	9	32	2
Looe	9	21	0
Trevose	7	15	1
Lundy	7	13	0
Longships & Lands End	10	10	1

Table 2. Links between European Marine Sites established by the European Union Habitats Directive.

EMS	Females	Males	Total shared seals	Number of connecting sites
Pembrokeshire	37	11	48	18
Lundy	9	4	13	7
Isles of Scilly	20	21	41	15
Iroise PNMI	0	2	2	1

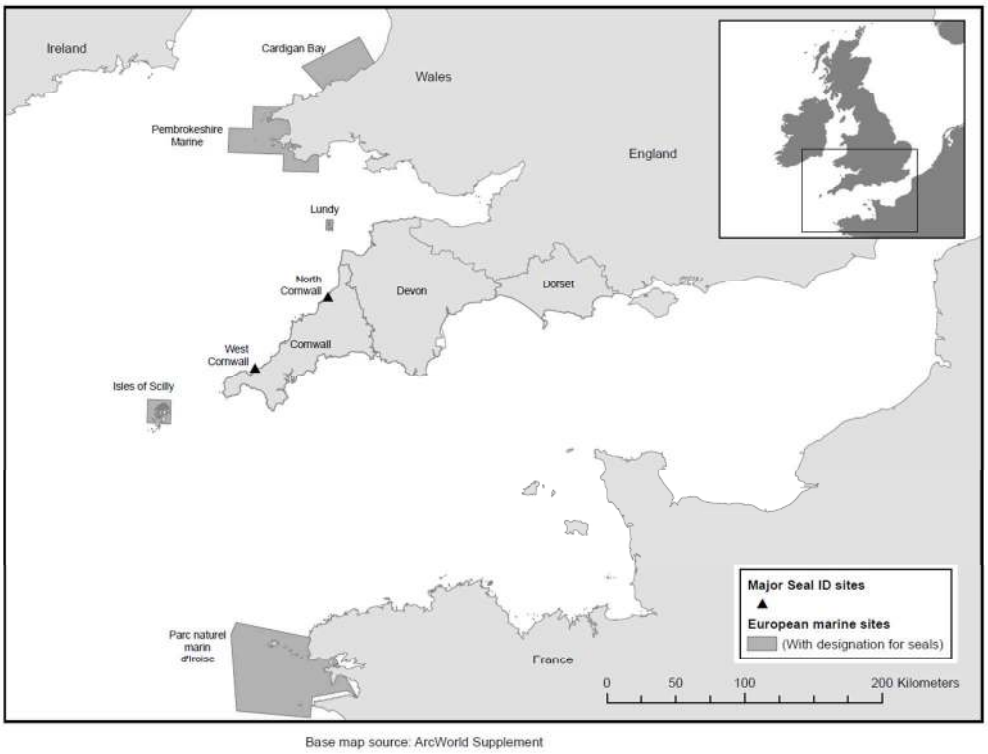

Figure 2. Two major seal ID sites and European Marine Sites (EMS) in SW Wales, SW England and NW France designated for seals.

345x260mm (96 x 96 DPI)

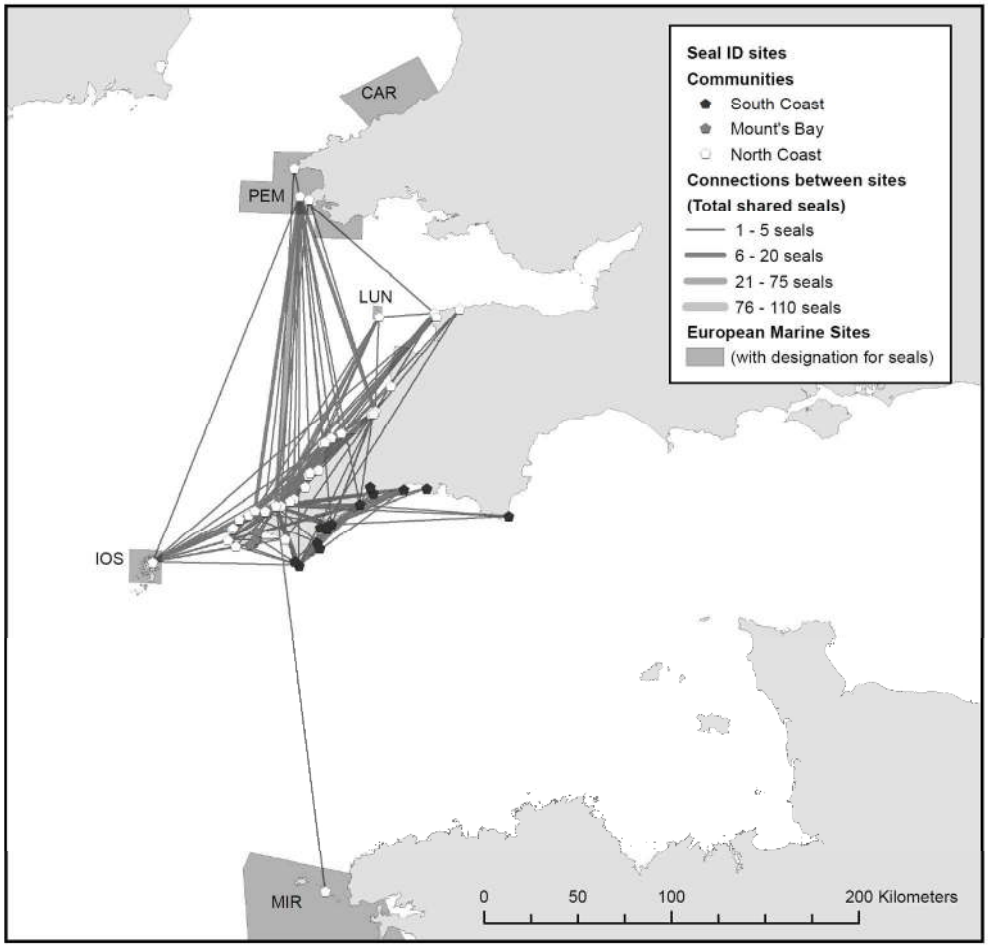

Figure 3. All shared seal PID connections between sites in the southwest UK.

504x481mm (96 x 96 DPI)

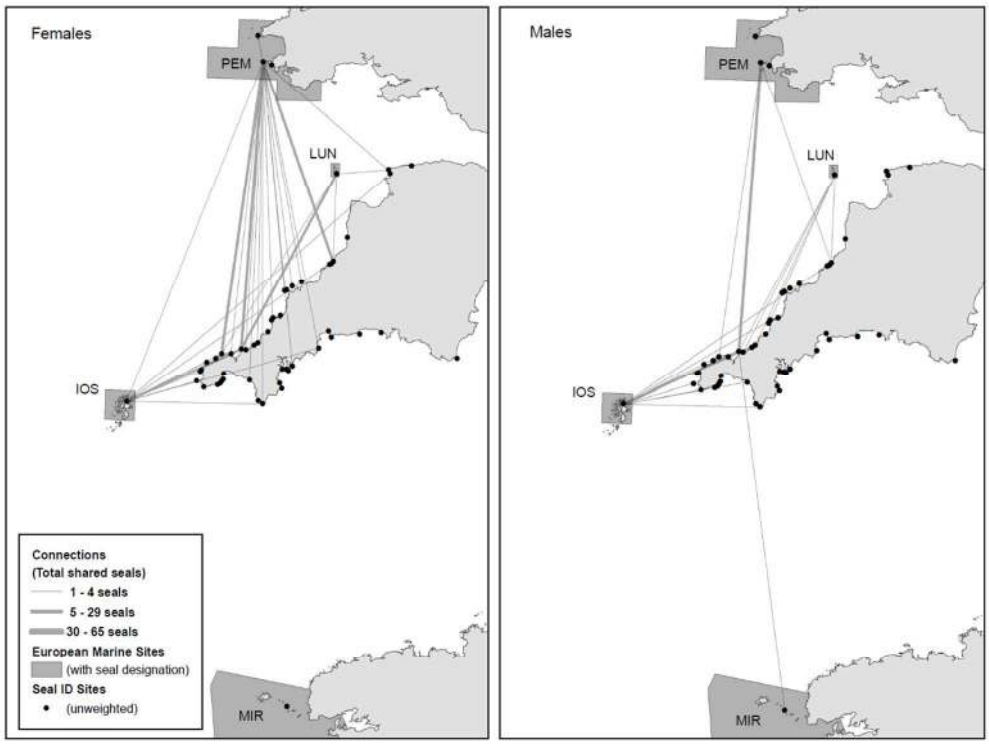

Figure 4. Female and male grey seal links between EMS and non designated sites across southwest England.

345x260mm (96 x 96 DPI)

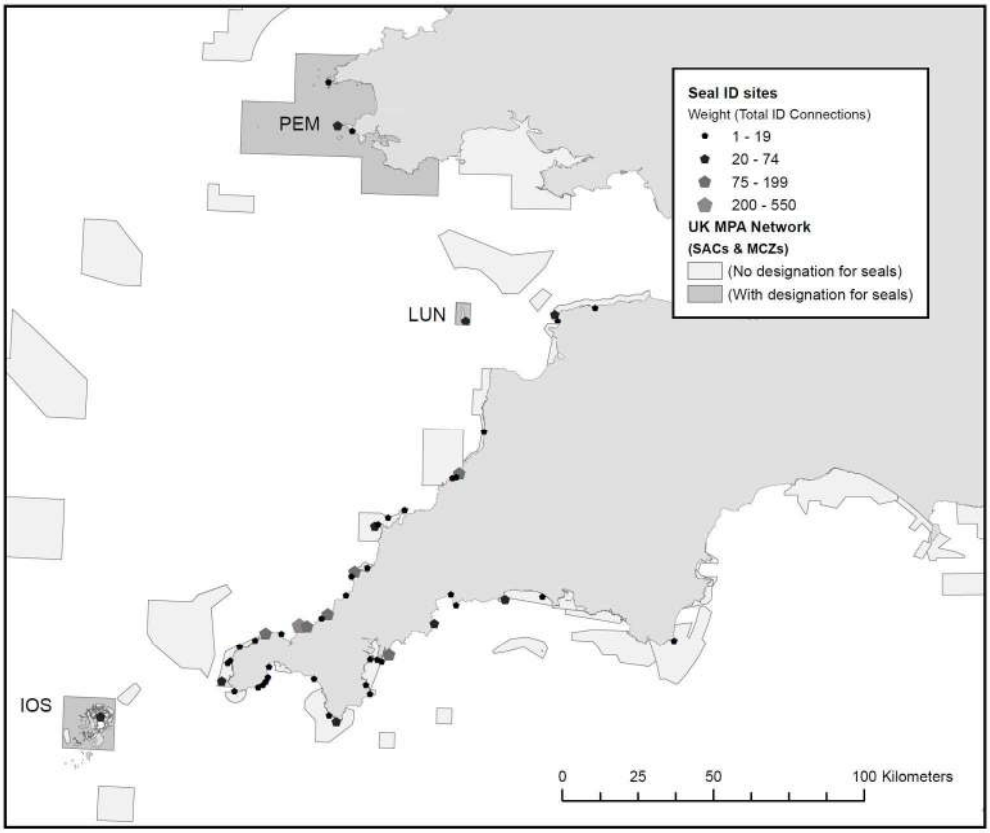

Figure 5. All shared seal sites and marine protected areas.

562x482mm (96 x 96 DPI)

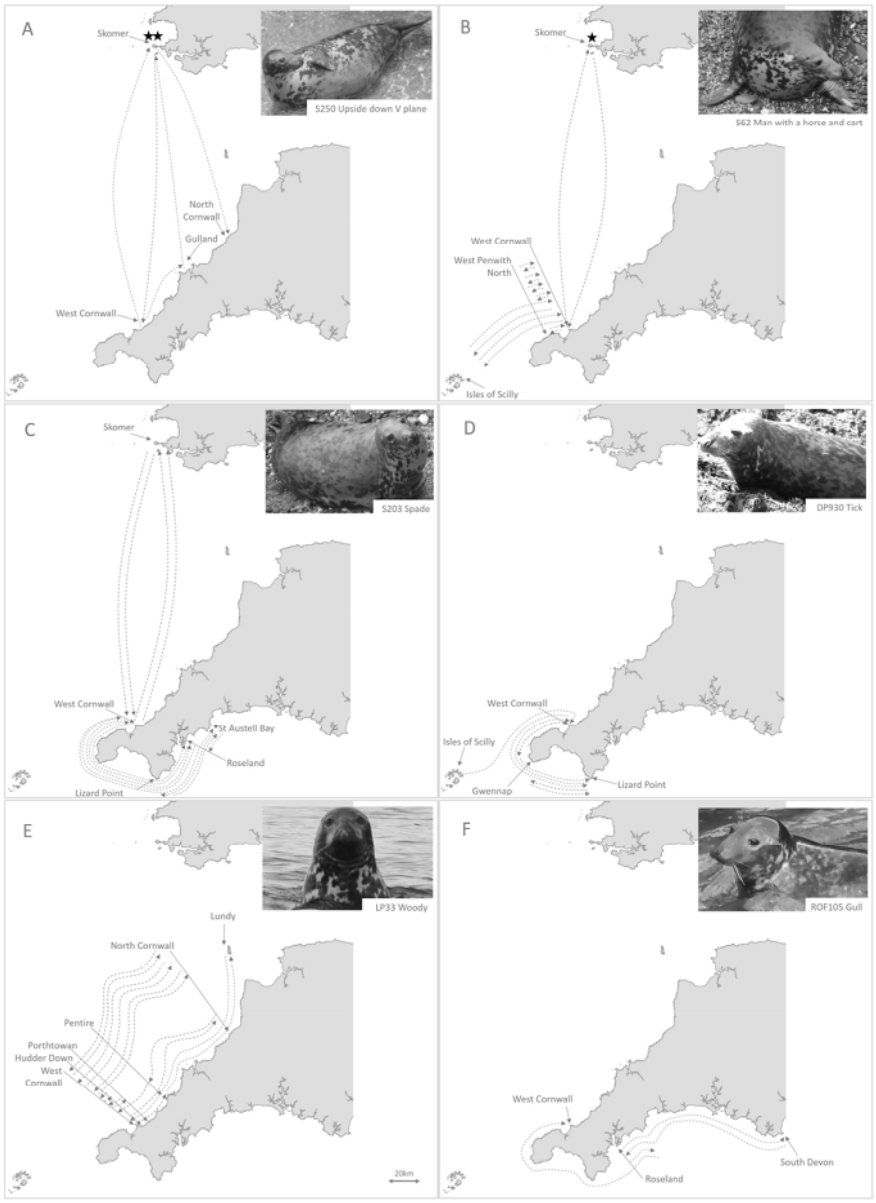

Figure 6. Maps showing individual seal movements as reconstructed by PID. Arrows indicate inferred movements between sites. Star indicates location of site where pupping was observed.

265x362mm (96 x 96 DPI)