

Method used to identify key seal haul-out sites in Scotland for designation under the Marine (Scotland) Act Section 117

¹⁺Chris Morris, ¹Callan Duck, ¹Mike Lonergan, ²John Baxter, ³Stuart Middlemas, ⁴Ian Walker

¹*NERC Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews*

²*Scottish Natural Heritage, Silvan House, Edinburgh*

³*Marine Scotland – Science, Freshwater Laboratory, Pitlochry*

⁴*Marine Scotland, Victoria Quay, Edinburgh*

⁺cdm21@st-andrews.ac.uk

April 2014

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Introduction

Section 117 of the Marine (Scotland) Act 2010 (the Act) provides for Scottish Ministers, after consulting the Natural Environment Research Council (NERC), to designate haul-out sites, which are considered suitable to protect seals from harassment, through an order in the Scottish Parliament. A haul-out site is a location on land where seals haul themselves out to rest. This paper aims to describe the method used to identify and select key seal haul-out sites for the purpose of the Act.

The Sea Mammal Research Unit (SMRU) generally conducts aerial surveys of seals during two different times of the year. The first survey period is during the harbour (or common) seal moult in August and produces minimum counts for harbour seals and grey seals around the entire Scottish coast approximately once every five years. The second survey period is during the grey seal breeding season from mid-September to early December and produces annual pup production estimates for approximately 60 of the main grey seal breeding colonies in Scotland. This represents the best available data with only very limited data available for other times of the year.

SMRU aerial survey methods are described in the Appendix.

The data from these two different survey types were used to create two separate lists of haul-out sites covering all of the existing Seal Management Areas and subdivisions (Figure 1). One list contains significant harbour and grey seal haul-out sites that were selected using data from the harbour seal moult surveys. The second list contains significant grey seal breeding colonies that are not already included in the first list.

This document describes the methodology for using aerial survey data to identify high density areas ('hotspots') for seals around the Scottish coast, which can be used to define seal haul-out sites/areas around these hotspots and to select significant haul-out sites for designation using a standardised procedure.

The process also included reviewing all the seal haul-out sites suggested by respondents to a Scottish Government consultation in spring 2011. This review indicated that no significant sites were missed and that a number of those meeting the criteria had indeed already been included.

Datasets and software used

Data collected during August helicopter surveys between 1996 and 2010 were used to identify key haul-out sites for both seal species.

The most recent data available from grey seal breeding surveys (i.e. 2005-2010) were used to identify additional sites for grey seals.

OS OpenData coastline shapefiles (2010) were used in *Manifold GIS 8.0* for identifying sites and defining site extent. *EDINA Digimap ShareGeo* shapefiles (2011) were used to define final site boundaries. The final site selection process was carried out using *MS Excel 2010*.

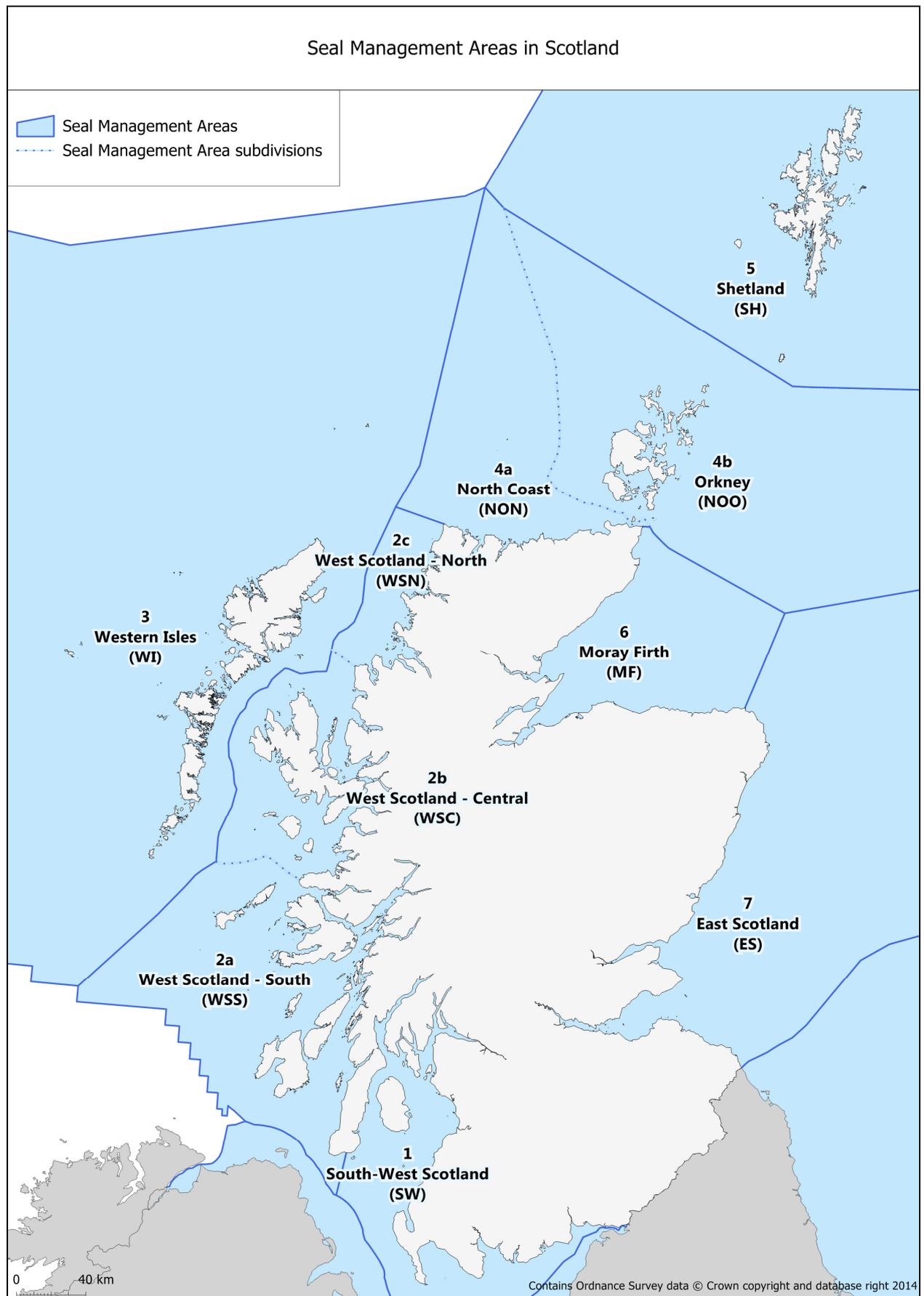


Figure 1. Seal Management Areas in Scotland. Dotted lines indicate subdivisions.

Producing a list of key haul-out sites based on August counts

Stage 1 - Identifying hotspots

First, a simplified coastline was generated from a high resolution *OS OpenData* mean low water shape file using *Manifold GIS*. Virtual Observation Points (VOPs) were placed at 100m intervals (or less for smaller islands and intertidal rocks) along the simplified coast, producing a total of 186,442 VOPs around Scotland (Figure 2).

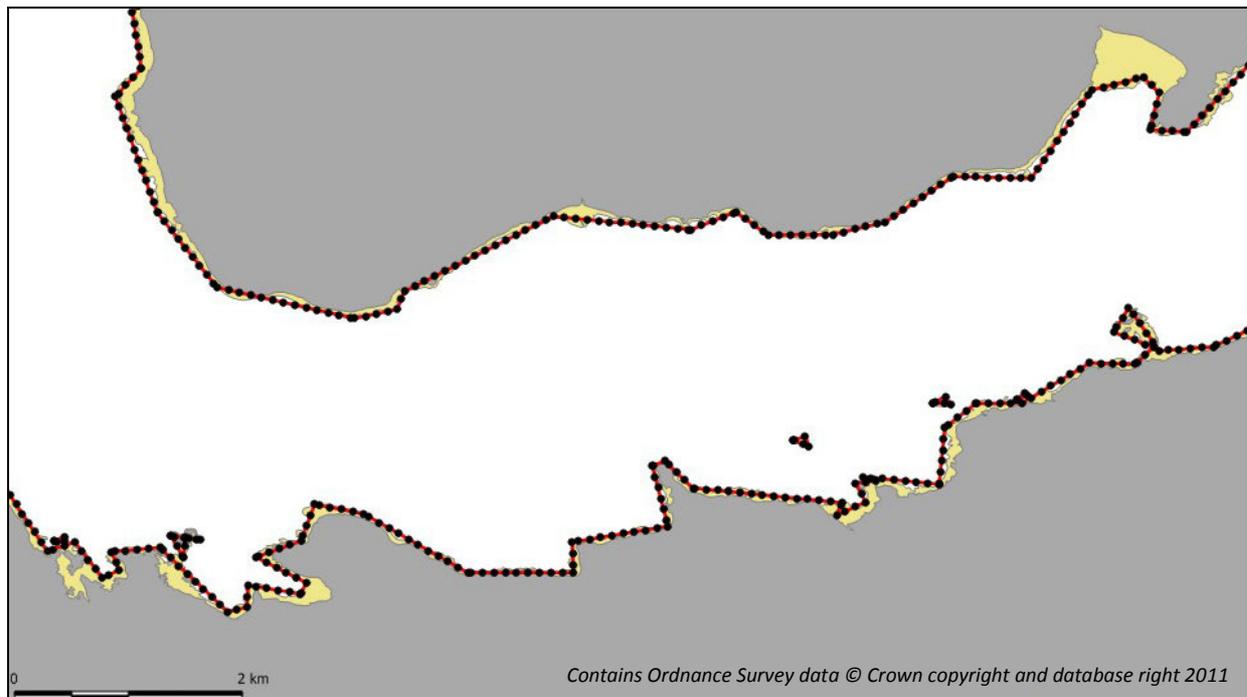


Figure 2. Virtual Observation Points (VOPs) every max 100m along a simplified low water coastline. Example shown is Loch Scridain, Mull.

The next step was to compile sighting histories of both species for each individual VOP. This was done within *Manifold GIS* by creating buffers with 300m radii around each VOP (Figure 3) and calculating – for each VOP – the sum of all sightings of each species that lie within the buffer boundary by year (1996-2010). This is equivalent to having an observer positioned at each VOP and recording all sightings within a 300m radius every time that part of the coast is surveyed (Table 1).

300m was chosen as an appropriate buffer radius for the following reasons:

- To ensure that all recorded seal sightings are contained within at least one buffer area. This is more or less the precision of the older data sets used (also taking into account that in some places the simplified coastline is further away from sighting locations than the actual coast).
- To a limited extent, this also helps deal with the fact that seals don't always haul out at exactly the same spot. So if, in one year, the same group of seals is recorded up to 600m further down the coast than in a previous year, both sightings will still lie within at least one individual buffer area.

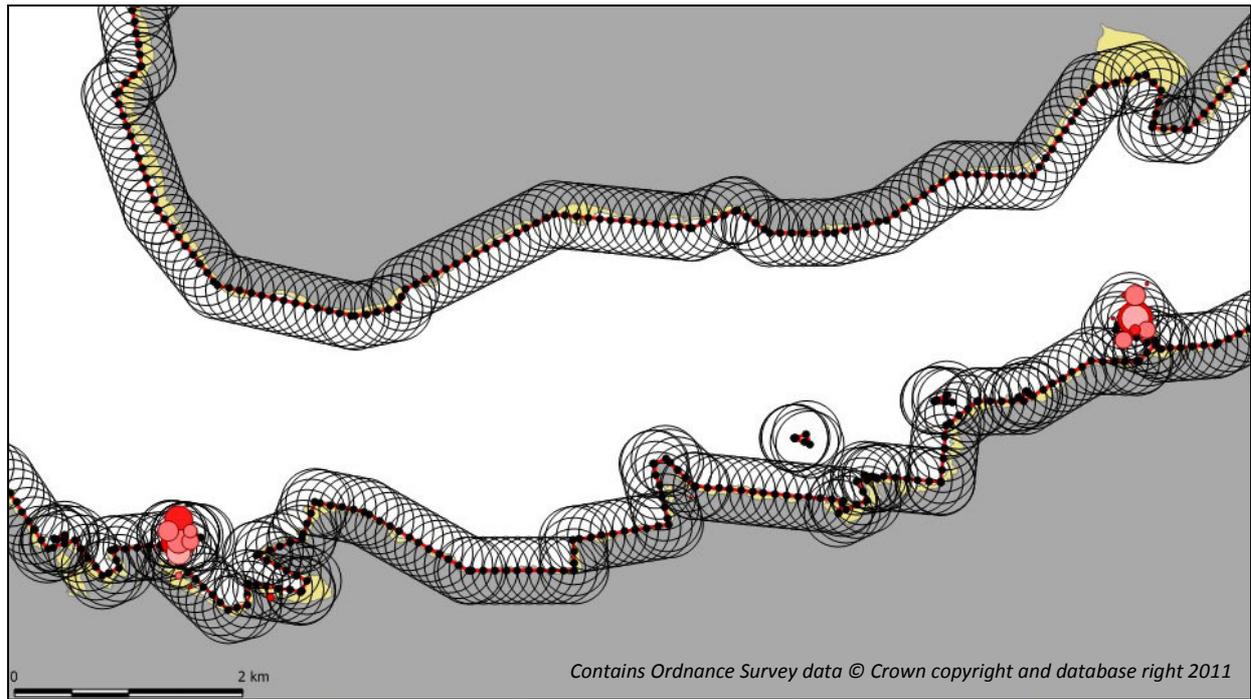


Figure 3. 300m buffer areas around every Virtual Observation Point (VOPs). Harbour seal sightings are also shown as filled red circles. Example shown is Loch Scridain, Mull.

Table 1. Example of possible sighting histories of harbour or grey seals for individual Virtual Observation Points (VOPs).

VOP	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
VOP-000001	0	n.s.	n.s.	n.s.	0	n.s.	n.s.	n.s.	n.s.	0	n.s.	n.s.	0	n.s.	n.s.
VOP-000002	52	n.s.	n.s.	n.s.	34	n.s.	n.s.	n.s.	n.s.	22	n.s.	n.s.	76	n.s.	n.s.
VOP-000003	52	n.s.	n.s.	n.s.	81	n.s.	n.s.	n.s.	n.s.	96	n.s.	n.s.	76	n.s.	n.s.
...															
VOP-186442	n.s.	13	n.s.	n.s.	n.s.	5	n.s.	n.s.	n.s.	n.s.	0	n.s.	10	14	5

n.s. = not surveyed

The individual sighting histories were then used to calculate a Time Weighted Average (TWA) of each species for each VOP using the following formula:

$$TWA = \frac{\sum_{i=1996}^{2010} 0.8^{2010-Y_i} \cdot C_i}{\sum_{i=1996}^{2010} 0.8^{2010-Y_i}}$$

TWA : Time-Weighted Average

C_i : Count in Year i

Y_i : Year counted (1996-2010)

Using TWAs allowed us to place a greater emphasis on more recent counts without having to ignore several years' worth of data. This is a more robust approach compared to using only the most recent counts as it reduces the effect of natural variability and adding new data does not change the overall picture (e.g. the selection of key sites) as drastically. A high weighting factor is ideal for sites where seal numbers are very stable over the entire period but is not suitable to reflect genuine changes in haul-out use. It benefits sites where seal numbers have declined over time, whereas a low weighting factor benefits sites where seal numbers have increased over time. The weighting factor 0.8 (from the possible range 0.0 – 1.0) reduces the weight of a sighting by 20% for every one year step back in time (Figure 4). We believe that this makes sense for a data set ranging over 15 years because it supports sites where seals have declined without disadvantaging sites where seals have increased.

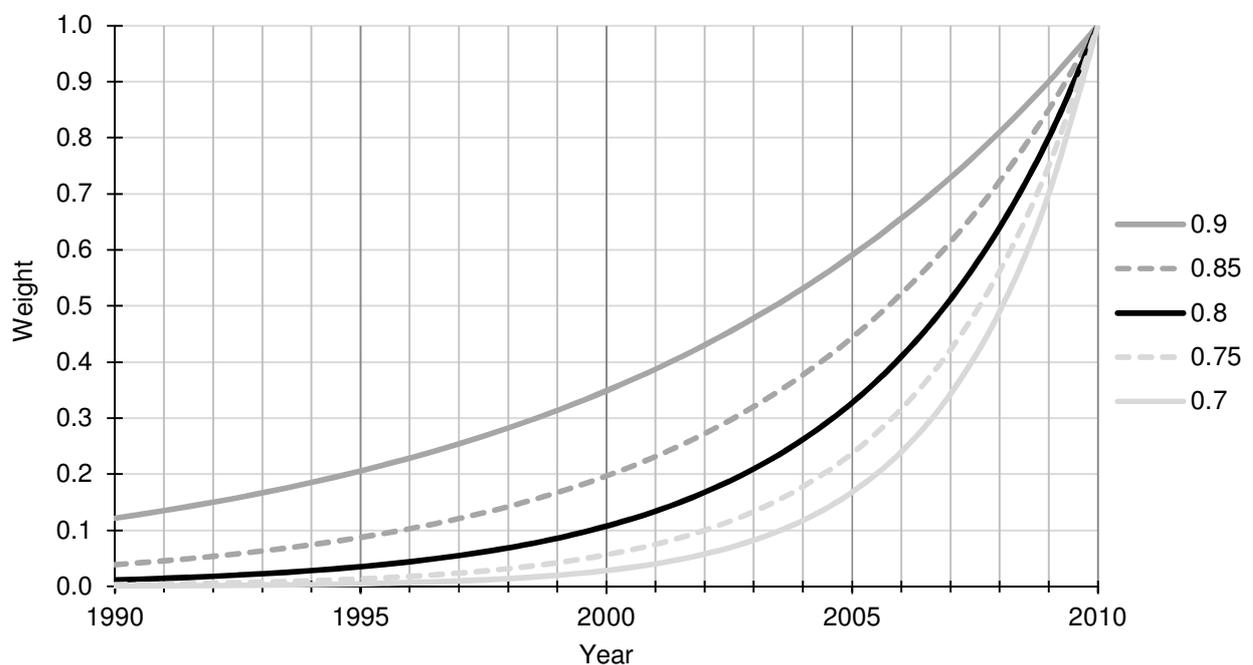


Figure 4. The influence of different weighting factors on the weight given to counts from 1990-2010.



Figure 5. Virtual Observation Point buffers coloured by Time Weighted Average of harbour seal sightings 1996-2010 (yellow = low to black = high). Example shown is Loch Scridain, Mull.

Hotspots were then highlighted by colouring the VOPs according to their TWAs (Figure 5). This can be done in various ways. The aim is to study areas at a finer resolution in the order established by the TWA values. All areas with a TWA greater than 50 were examined first and site boundaries defined (see Stage 2), before moving to TWAs with values between 30-50, 20-30, 10-20 etc. This was continued until at least 50% of harbour seal and grey seal populations were covered in each Seal Management Area and subdivision by a combination of all existing Special Areas of Conservation (SACs) for seals and the newly identified haul-out sites. This minimum figure was requested by Marine Scotland and Scottish Natural Heritage because it was considered to represent a good starting point in terms of achieving a balance between maximising seal protection while minimising potential implications for other sustainable activities around the coast. This minimum figure was increased for certain species in specific areas which showed a decline in numbers for that species (see Table 2 below). This was done to reflect the requirement for greater protection in such circumstances. The Seal Management Areas and subdivisions are shown in Figure 1.

Stage 2 - Defining individual haul-out sites

Site boundaries were defined by overlaying all available seal sighting data 1996-2010 onto detailed *OS OpenData* maps within *Manifold GIS* and drawing a polygon shape around parts of the coast, small islands and skerries that contained seal sightings (Figure 6A). This is a somewhat arbitrary process. It is not possible to be certain about where seals may or may not haul-out and it is therefore always possible for 'unimportant rocks' to be included and 'important rocks' to be excluded.

As described above for buffer areas, sighting histories and TWAs were calculated for each newly identified and defined site.

After the selection process was completed, as described in the next section, a GIS shapefile was created containing the detailed areas covered by each site (Figure 6B). This was done

using Scotland mean high and low water shapefiles extracted from the *Digimap Ordnance Survey Collection* by Pope (2011). The final site boundaries for a designated site are defined by a minimum bounding rectangle around these detailed areas plus a 100m buffer border.

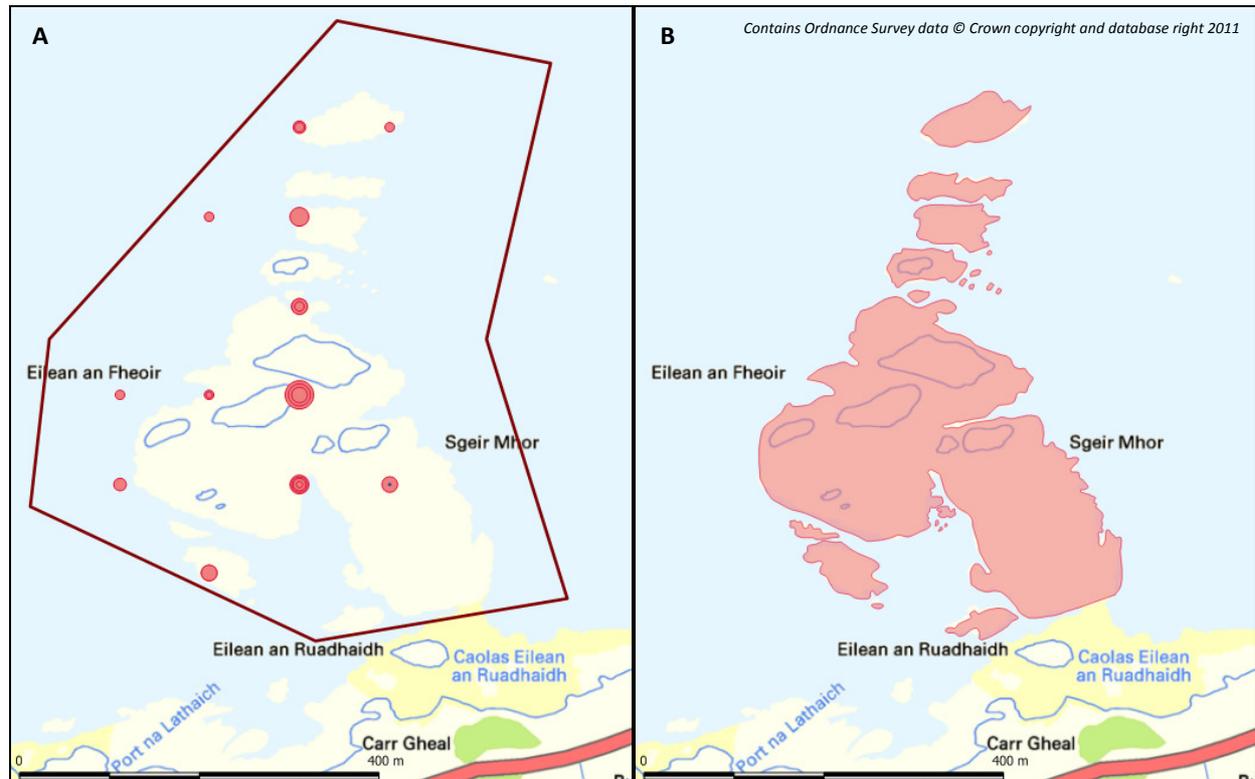


Figure 6. **A** Shows the Polygon used to calculate the sighting history for Eilean an Fheoir, a harbour seal haul-out site in Loch Scridain, Mull. **B** Shows the detailed area extracted from the *Digimap Ordnance Survey Collection* shapefiles.

Stage 3 - Selecting sites for designation

All identified sites were included in an *MS Excel 2010* database containing a harbour seal site list and a grey seal site list ranked by TWA, together with all associated information (e.g. Seal Management Area and subdivision, site name and location, TWAs for both species, grid references (of each site's centroid)). Sites shared by both species were included in both species' lists. A site was defined as being a shared site if both species contributed at least 10% to the total number of seals based on TWAs or if the site had been identified for both species independently as a haul-out site.

The final list of sites for designation was produced using the site selection criteria described below. This selection process was carried out for both species independently.

Selection criteria

1) Primary selection criterion:

For each Seal Management Area and subdivision, a minimum population coverage target was set for each species, as given in Table 2. A minimum of at least 50% was set in all Seal Management Areas and subdivisions where seal populations were either stable or increasing. A significantly larger proportion of the population was set for harbour seals in

Seal Management Areas and subdivisions where this species' populations have declined significantly and which feature seal conservation areas (<http://www.scotland.gov.uk/Resource/Doc/295194/0112738.pdf>).

All seal SACs were included in the minimum coverage target so sites identified during the previous steps that lay within an SAC were excluded from this process. Starting with the site with the highest TWA in each Seal Management Area and subdivision, sites were added to the lists until the appropriate minimum population coverage was achieved for each species. For those Seal Management Areas and subdivisions, where the target was set above the 50% cut-off used for stages 1 and 2, additional sites were identified where necessary in order to reach the higher target.

2) Secondary selection criteria:

In addition to the sites selected by the primary selection criterion, all sites that contained a certain percentage of the Seal Management Area's TWA population were also added to the list:

- for harbour seals: sites \geq 5% of the Seal Management Area population
- for grey seals: sites \geq 10% of the Seal Management Area population

These criteria were added to ensure the inclusion of any sites considered to be significant to that Seal Management Area's wider population.

Table 2. Selection criteria set for harbour and grey seals. A minimum of at least 50% of the local population of each seal species was set as the primary selection criteria. This was increased for harbour seals to 60% in the Western Isles and to 80% in all northern and eastern Seal Management Areas and subdivisions where this species has been in decline in recent years.

Seal Management Area (SMA) or subdivision	Primary selection criteria:		Secondary selection criteria:	
	Minimum coverage targets		Site size relative to SMA's TWA	
	Harbour seals	Grey seals	Harbour seals	Grey seals
1 South-West Scotland	50%	50%	\geq 5%	\geq 10%
2a West Scotland - South	50%	50%	\geq 5%	\geq 10%
2b West Scotland - Central	50%	50%	\geq 5%	\geq 10%
2c West Scotland - North	50%	50%	\geq 5%	\geq 10%
3 Western Isles	65%	56%	\geq 5%	\geq 10%
4a North Coast	80%	50%	\geq 5%	\geq 10%
4b Orkney	80%	50%	\geq 5%	\geq 10%
5 Shetland	80%	50%	\geq 5%	\geq 10%
6 Moray Firth	80%	50%	\geq 5%	\geq 10%
7 East Scotland	80%	50%	\geq 5%	\geq 10%

This selection process produced a list containing a total of 149 seal haul-out sites. Table 3 shows in detail how many sites were selected and the criteria on which selection was based. Of these 149 sites, 115 sites were selected for harbour seals only; 27 sites were selected for grey seals only, and 7 sites were selected for both species. Most sites (144) were selected under the

primary selection criteria, only 5 sites were added under the secondary selection criteria. Note that a number of the 115 'harbour seal' sites and a number of the 27 'grey seal' sites were considered to contain sufficient numbers of the other species for them to be identified as shared sites in the final list. Figure 7 shows a map of Scotland with these 149 sites marked by purple circles.

Table 3. The number of sites selected per Seal Management Area and subdivision based on the primary or secondary criteria for harbour and grey seals (excluding SACs). These sites are marked by purple circles in Figure 7.

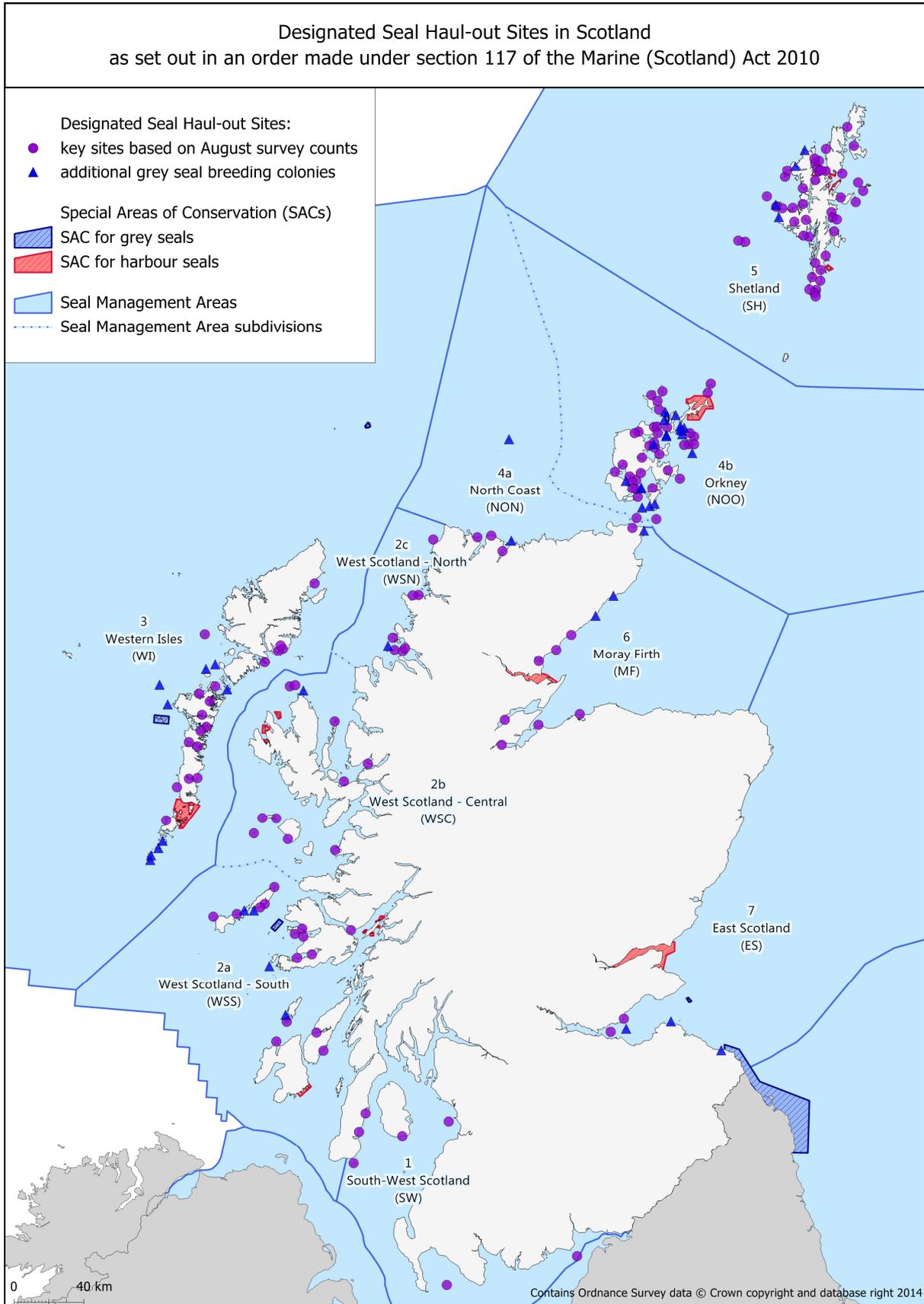
Seal Management Area (SMA) or subdivision		Sites selected based on:						
		Primary selection criteria:			Secondary selection criteria:			
		Minimum coverage targets			Site size relative to SMA's TWA			
		Both	Harbour	Grey	Both	Harbour	Grey	Total sites
1	South-West Scotland	1	2	3	0	1	0	7
2a	West Scotland - South	0	12	3	0	0	0	15
2b	West Scotland - Central	1	4	5	0	0	0	10
2c	West Scotland - North	0	3	4	0	0	0	7
3	Western Isles	0	17	1	0	0	0	18
4a	North Coast	0	2	2	0	0	0	4
4b	Orkney	2	30	4	0	0	0	36
5	Shetland	3	36	4	0	0	0	43
6	Moray Firth	0	4	0	0	2	1	7
7	East Scotland	0	1	0	0	1	0	2
	Total	7	111	26	0	4	1	149

Producing a list of additional grey seal breeding colonies

Compared to the process required to develop the first list of key haul-out sites it was a much simpler task to produce a list of grey seal breeding colonies. All major grey seal colonies in Scotland are well-known and surveyed regularly to obtain pup production estimates. It was decided to include all known grey seal breeding colonies in Scotland where at least 20 pups are born each year and which are not already covered by seal SACs or the original list of key haul-out sites.

There were 17 breeding colonies already covered by existing seal SACs, another 15 were covered by sites on the list of key haul-out sites. The above criteria identified a list of 45 additional grey seal breeding colonies for designation. Figure 7 shows a map of Scotland with these 45 sites marked by blue triangles.

Figure 7. Map of Scotland indicating the location of proposed Designated Seal Haul-out Sites in Scotland. Sites on the original list of key haul-out sites are marked by purple circles; additional grey seal breeding colonies are marked by blue triangles.



Limitations of data and methods used

Large datasets for both harbour and grey seals were available for designating seal haul-out sites but there remain large gaps in our knowledge waiting to be filled. Although, we believe the process described here is an appropriate way of selecting sites in a standardised manner, it is important to point out that a number of decisions had to be based on expert judgement using the best data available.

Some of the main issues to bear in mind are:

- The only extensive seal sighting dataset that covers the entire Scottish coast is exclusively from August surveys. This means that the majority of sites have been selected based on sightings and counts in August only. Seasonal variability is not taken into account although opportunistic data have shown that, at least in some places, there can be significant differences in the numbers of seals between seasons.
- The process used for selecting key seal haul-outs favours large sites over smaller sites. It assumes that the number of seals hauled out is a measure of the sites importance to the wider population. There may be other reasons that sites are important to seal populations but at present it is not possible to quantify these in any meaningful way and the list of designated sites has been produced with the only available metric.
- It was not possible to assess each seal haul-out site in a reliable and consistent manner to take into account the potential risk of harassment. This means that seals at some sites included in the lists may be unlikely to be subjected to activities that might cause harassment. This is considered a positive factor in the selection process since it means that significant seal haul-out sites are included whether or not they are potentially at risk or not. They are therefore protected against the possibility of future harassment.
- It would be interesting to compare the results using different buffer sizes (500m, 1km etc.) for the VOPs. The outcome is unlikely to be very different but larger buffer areas could potentially highlight additional sites where seals are dispersed in several smaller groups over larger areas or where the precise location is especially variable between surveys.
- The weighting factor of 0.8 used to calculate all the Time Weighted Averages (TWAs) is a value which we believe gives an appropriate relative weight to data collected over a 15 year period (see Figure 4).
- Seals are not aware of boundaries drawn on maps. In some cases it is easy to define the boundaries of a site, e.g. a small offshore island. In other cases it is very difficult to decide where one site ends and another site begins as seals can haul-out in slightly different places during different haul-out periods (depending on wind direction etc.). In high density areas it is also not straightforward to define separate sites. Using a standard minimum distance to distinguish between separate sites was not considered to be very useful. Therefore each site was studied and defined individually using our best judgement. Regardless of the method used, there is a great amount of variability in the size of individual sites.

Acknowledgements

We would like to thank all those who helped collect or provided the data used in the process presented in this paper. These include: SNH Orkney and Shetland and volunteers for ground counts of grey seal pups, Fife Seal Group / Forth Seabird Group and volunteers for ground counts of grey seal pups in the inner Firth of Forth.

We are very grateful for the expertise enthusiastically provided by the companies supplying the survey aircrafts and pilots: *PDG Helicopters*, *Giles Aviation* and *Caledonian Air Surveys*.

All data used in this study are from surveys funded by the Natural Environment Research Council (NERC) and/or Scottish Natural Heritage (SNH).

Clint Blight repeatedly provided excellent advice and support for the work carried out using Manifold GIS.

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Appendix – SMRU aerial survey methods

The Sea Mammal Research Unit (SMRU) at the Scottish Oceans Institute, University of St Andrews, carries out surveys of harbour seals and grey seals to contribute to the Natural Environment Research Council's (NERC) statutory obligations under the Marine (Scotland) Act 2010 and the Conservation of Seals Act 1970 to provide 'scientific advice on matter relating to the management of seal populations' to the UK government. An essential component of this advice is information on the size and distribution of seal populations around the UK, particularly in Scotland where over 85% of both species of UK seals are found. The annually submitted advice can be found on SMRU's website ([link to SCOS Reports](#)).

SMRU harbour seal moult surveys

Helicopter surveys

This method is generally applied to survey parts of the Scottish coast each year and produces a complete estimate for the whole of Scotland approximately every five years.

During the harbour seal moult in August, helicopter surveys are carried out using a thermal imager which is sensitive to infrared radiation in the 8 - 14 μm wavebands and is equipped with a dual telescope (x2.5 and x9 magnification). The imager is mounted on a pan-and-tilt head and operated out of the helicopter window.

When surveying, the helicopter follows the contours of the coast operating at a height of 150-250 m and a distance of 300-500 m offshore to ensure that seals are not disturbed. A digital video camcorder, attached to the imager, provides a real colour image to match the thermal image. Both images are displayed continuously on a monitor placed in front of the camera operator and simultaneously recorded to a digital video recorder. Seals are detected and counted on the monitor using the thermal image. For each sighting the location, time, species and number of seals are recorded directly onto Ordnance Survey 1:50 000 maps. Since 2007, most groups of seals are also photographed using a digital SLR camera equipped with an image-stabilised 70-300mm lens.

In general, differentiating between harbour and grey seals using a thermal image is possible on account of their different thermal profile, size and head-shape. When hauled out, their group structure also differs. Grey seals form tight and disorganised aggregations close to the water while harbour seals have greater inter-individual distances and are often a bit further from the water's edge. Species identification in the field is aided by the 'real' camcorder image and by direct observation using binoculars. Species identity and the number of seals in groups are later confirmed by reviewing both the digital thermal video and the digital still images.

To maximise numbers counted, surveys are carried out no more than two hours before or after the local low tide times occurring between approximately 12:00 and 17:30hrs local time. To further reduce the effects of environmental variables on number of seals counted, surveys are not carried out on rainy days. The thermal imager cannot 'see' through heavy rain and seals often abandon their haul-out sites and return to the water in medium to heavy prolonged rain.

Fixed-wing surveys

Certain areas on the east coast of Scotland (mainly the Moray Firth but also the Tay and Eden estuaries) are surveyed almost annually using fixed-wing aircraft, if not covered by the helicopter survey. The major seal haul-out sites in these areas are well known. They are often situated on sandbanks making it easier to spot seals without the help of a thermal imager. All groups of seals are photographed through the aircraft's side windows using a handheld digital SLR camera and recorded onto paper maps.

As described above for helicopter surveys these fixed-wing surveys are only carried out within certain tidal windows and in suitable weather conditions.

SMRU grey seal pup surveys

Grey seals return each year to traditional colonies to breed. Not only do females return to the same location within a colony, but they regularly return to the colony at which they were born. The timing of breeding varies around the Scottish coast. The earliest colonies are in the Inner Hebrides, followed by the Outer Hebrides, Shetland and Orkney. Latest of all are the colonies in the Firth of Forth. In each area, breeding occurs over approximately two months, with individual pups remaining on their breeding colony for approximately five weeks before departing to sea. A series of up to five aerial surveys are flown over the main breeding colonies by fixed-wing aircraft, at intervals of 10 to 13 days (weather permitting). Pups are counted from high resolution vertical aerial images and we use a maximum likelihood model to estimate the total number of pups born at each colony from the series of counts. Annual surveys were carried out up to 2010.