Scientific Advice on Matters Related to the Management of Seal Populations: 2014

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Executive Summary

Under the Conservation of Seals Act 1970 and the Marine (Scotland) Act 2010, the Natural Environment Research Council (NERC) has a duty to provide scientific advice to government on matters related to the management of seal populations. NERC has appointed a Special Committee on Seals (SCOS) to formulate this advice. Questions on a wide range of management and conservation issues are received from the UK government and devolved administrations. In 2014, 51 questions were addressed by SCOS.

Population trends

Grey seal population trends are assessed from the counts of pups born during the autumn breeding season. Air survey methods changed to a completely digital system in 2012. These air surveys resulted in a pup production estimate for the UK of 56,988 (95% CI 56,317-57,683). To then estimate the total grey seal population size in 2013, trajectories from a population dynamics model using the 2012 pup counts and population demographic parameters (including the estimates for the additional colonies not surveyed regularly) gave a total UK population of 111,600 (95% CI 92,000-137,900).

This is approximately the same as the estimate reported for 2012, despite an increase in the pup production. The pup counts have increased in the last two surveys, which has resulted in a lack of fit of the model to the pup production estimates in recent years. In addition, the estimated adult survival rate from the model was very high and the maximum pup survival rate was very low, which suggests some other parameters, such as inter-annual variation in fecundity could be causing a mismatch between the estimates from the model and the pup production data. Variation in fecundity and survival is being investigated and in addition biases in the independent and the pup production estimates will be investigated further for reporting at SCOS 2015.

Harbour seals are counted while they are on land during their August moult, giving a minimum estimate of population size. Not all areas are counted every year but the aim is to cover the UK coast every 5 years. Combining the most recent counts (2007-2013) gives a total of 26,290 counted in the UK. Scaling this by the estimated proportion hauled out produced an estimated total population for the UK in 2013 of 36,500 (approximate 95% CI 29,900 – 49,700).

Harbour seal counts were stable or increasing until around 2000 when declines were seen in Shetland (which declined by 30% between 2000 and the most recent count in 2009), Orkney (down 78% between 2000 and 2013) and the Firth of Tay (down 93% between 2000 and 2013). However, other regions have been largely continually stable (west coast of Highland region and the Outer Hebrides). Counts along the English east coast were very similar to those reported in 2012.

Fecundity and survival in adult female grey seals

Survival rates and fecundity estimates for adult females breeding at two colonies with contrasting population trajectories, North Rona and the Isle of May (increasing at the Isle of May, declining at North Rona), have been estimated from re-sightings of permanently marked animals. An integrated analysis of resightings, post-partum mass and reproductive success using data collected from 1987 to 2012 was used to explore the relationship between mass and the probability of breeding (individual fecundity). Results suggest differences between the colonies. Overall fecundity estimates differed between sites with a general estimate of 0.77 (0.750, 0.792 95% Bayesian credible intervals) for North Rona and 0.86 (0.835, 0.882 Bayesian credible intervals) for the Isle of May. These estimates are lower than previous estimates for UK grey seals and are being used to set the priors in the Bayesian state space model which converts the grey pup production counts to a total population size.

Adult survival (averaged over all years) at the Isle of May was not related to mass and was estimated to be generally high at 0.926 (95% Bayesian credible interval 0.792, 0.977). At North Rona annual survival rates were estimated to be 0.936 (95% Bayesian credible interval 0.904, 0.961). Again, these empirical estimates are being used in the population model.

Harbour and grey seal diet

Research into the causes of the decline in harbour seals in some areas of Scotland is continuing. One hypothesis is that competition with grey seals for prey is a driver, as grey seals are increasing in areas where harbour seals are declining. The results of diet studies carried out in 2010/11 for evidence of prey overlap between the two seal species have now been analysed. A wide range of prey types was consumed by harbour seals namely: sandeels, gadoids, flatfish, scorpion fish, sandy benthic fish, pelagic fish and cephalopods. Diet composition varied seasonally and regionally and prey diversity and diet quality also showed some regional and seasonal variation. This is the first comprehensive assessment of harbour seal diet in the UK. Diet composition for grey seals has been assessed at a UK wide scale previously in 1985 and 2002 in addition to the 2010/11 study. The major prey species were sandeels and large gadoids; however, some marked differences were seen in 2010/11 compared to 2002 (and 1985). In 2010/11, the proportion of gadoids in the diet increased in Orkney and Shetland but decreased in the Inner and Outer Hebrides and the central North Sea. Conversely, in 2010/11, the proportion of sandeels in the diet decreased in Orkney and Shetland but increased in the Outer Hebrides and central North Sea.

Comparison of diet composition, prey diversity and diet quality between harbour and grey seals found some seasonal and regional differences but no overall consistent pattern emerges to link these differences with observed regional changes in abundance in the two species. More detailed analysis of this very large dataset is continuing but there is clearly no obvious overlap that could readily explain the decline of harbour seals.

Unexplained seal deaths

In relation to deaths of harbour seals due to physical trauma, the link between traumatic mortality and ducted propellers has been tested using scale models in industrial test facilities. The results showed that the wounds were completely consistent with interactions between seals and ducted propellers as the model seals in the test tank with ducted propellers produced similar wounds whilst non-ducted propellers did not. A definitive observed encounter between a seal and a vessel has not yet been recorded but further research is designed to track the fine scale, real-time movements of tagged seals in areas where encounters are likely to occur and during the development of a port where increased vessel traffic is anticipated.

Seals and salmon

Priority areas for research on the interactions between seals and salmon netting stations are focussed on improved net design, improved acoustic deterrent devices (ADDs) and a study of the long term effectiveness, and seal habituation to, ADDs. Although catches were again higher when ADDs were in use, results obtained in 2013 were less marked than previously. Modified nets, including a narrower entrance to the fish court and changes to the netting to reduce the chances of seals chasing fish into the corners of the net, are being tested. The results are difficult to interpret, as the modified net yielded a higher proportion of damaged fish than the traditional net, but the actual landings per unit effort were significantly higher at the modified net. Future work will focus on further modifications as well as why some seals may be less responsive to ADDs than others.

Seals and marine renewable energy

In 2014 SMRU was contracted by Scottish Government to develop a technical solution to detect and track marine mammals in the vicinity of an operational tidal turbine. This study will be carried out wherever the first Scottish turbine is established (likely to be in the Pentland Firth). A threefold approach will be taken: Active Sonar, Passive Acoustic Monitoring (it is proposed that PAM will be able to track seals fitted with acoustic pingers) and opportunistic Video Surveillance to detect actual collision events for a sub set of the deployments. This proof-of-concept project will report in mid-2015. It is anticipated that data capable of usefully informing collision risk models will be gathered the following year.

Seal bycatch

Annual reports are submitted to Defra on the implementation of Council Regulation (EC) No. 812/2004 and Council Directive 92/43/EE in relation to estimates of protected species bycatch. Data on numbers of dolphins, porpoises and seals bycaught by ICES division are reported. The information for seals is given, the majority of which are grey seals. The overall estimate for 2013 was 391 (95% confidence limits 234, 1146) for the Irish and Celtic Seas and Channel (ICES subdivisions VIIa,d,e,f,g,h and j).

Scientific Advice

Background

Under the Conservation of Seals Act 1970 and the Marine (Scotland) Act 2010, the Natural Environment Research Council (NERC) has a duty to provide scientific advice to government on matters related to the management of seal populations. NERC has appointed a Special Committee on Seals (SCOS) to formulate this advice so that it may discharge this statutory duty. Terms of Reference for SCOS and its current membership are given in ANNEX I.

Formal advice is given annually based on the latest scientific information provided to SCOS by the Sea Mammal Research Unit (SMRU). SMRU is an interdisciplinary research group at the University of St Andrews which receives National Capability funding from NERC to fulfil its statutory requirements and is a delivery partner of the National Oceanography Centre. SMRU also provides government with scientific reviews of licence applications to shoot seals; information and advice in response to parliamentary questions and correspondence; and responds on behalf of NERC to questions raised by government departments about the management of marine mammals in general.

This report provides scientific advice on matters related to the management of seal populations for the year 2013. It begins with some general information on British seals, gives information on their current status, and addresses specific questions raised by the Marine Scotland (MS) and the Department of the Environment, Food and Rural Affairs (Defra) and Natural Resources Wales (NRW).

Appended to the main report are briefing papers which provide additional scientific background for the advice.

As with most publicly funded bodies in the UK, SMRU's long-term funding prospects involve a reduction in spending in cash terms that represents a substantial reduction in real terms into the foreseeable future. This reduction continues to have a negative impact on the underpinning scientific information on which this advice is based.

General information on British seals

Two species of seal live and breed in UK waters: grey seals (*Halichoerus grypus*) and harbour (also called common) seals (*Phoca vitulina*). Grey seals only occur in the North Atlantic, Barents and Baltic Sea with their main concentrations on the east coast of Canada and United States of America and in north-west Europe. Harbour seals have a circumpolar distribution in the Northern Hemisphere and are divided into five sub-species. The population in European waters represents one subspecies (*Phoca vitulina vitulina*). Other species occasionally occur in UK coastal waters, including ringed seals (*Phoca hispida*), harp seals (*Phoca groenlandica*), bearded seals (*Erignathus barbatus*) and hooded seals (*Cystophora crystata*), all of which are Arctic species.

Grey seals

Grey seals are the larger of the two resident UK seal species. Adult males can weigh over 300kg while the females weigh around 150-200kg. Grey seals are long-lived animals. Males may live for over 20 years and begin to breed from about age 10. Females often live for over 30 years and begin to breed at about age 5.

They are generalist feeders, foraging mainly on the sea bed at depths of up to 100m although they are probably capable of feeding at all the depths found across the UK continental shelf. They take a wide variety of prey including sandeels, gadoids (cod, whiting, haddock, ling), and flatfish (plaice, sole, flounder, dab). Amongst these, sandeels are typically the predominant prey species. Diet varies seasonally and from region to region. Food requirements depend on the size of the seal and fat content (oiliness) of the prey, but an average consumption estimate is 4 to 7 kg per seal per day depending on the prey species.

Grey seals forage in the open sea and return regularly to haul out on land where they rest, moult and breed. They may range widely to forage and frequently travel over 100km between haulout sites. Foraging trips can last anywhere between 1 and 30 days. Compared with other times of the year, grey seals in the UK spend longer hauled out during their annual moult (between December and April) and during their breeding season (between August and December). Tracking of individual seals has shown that most foraging probably occurs within 100km of a haulout site although they can feed up to several hundred kilometres offshore. Individual grey seals based at a specific haulout site often make repeated trips to the same region offshore, but will occasionally move to a new haulout site and begin foraging in a new region. Movements of grey seals between haulout sites in the North Sea and the Outer Hebrides have been recorded.

There are two centres of grey seal abundance in the North Atlantic; one in Canada and the north-east USA, centred on Nova Scotia and the Gulf of St Lawrence and the other around the coast of the UK especially in Scottish coastal waters. Populations in Canada, the USA, the UK and the Baltic are increasing, although numbers are still relatively low in the Baltic where the population was drastically reduced by human exploitation and reproductive failure probably due to pollution. However, there are clear indications of a slowing down in population growth in the UK and Canadian populations in recent years.

Approximately 38% of the world's grey seals breed in the UK and 88% of these breed at colonies in Scotland with the main concentrations in the Outer Hebrides and in Orkney. There are also breeding colonies in Shetland, on the north and east coasts of mainland Britain and in SW England and Wales. Although the number of pups throughout Britain has grown steadily since the 1960s when records began, there is clear evidence that the population growth is levelling off in all areas except the central and southern North Sea where growth rates remain high. The numbers born in the Hebrides have remained approximately constant since 1992 and growth has been levelling off in Orkney since the late 1990s.

In the UK, grey seals typically breed on remote uninhabited islands or coasts and in small numbers in caves. Preferred breeding locations allow females with young pups to move inland away from busy beaches and storm surges. Seals breeding on exposed, cliff-backed beaches and in caves may have limited opportunity to avoid storm surges and may experience higher levels of pup mortality as a result. Breeding colonies vary considerably in size; at the smallest only a handful of pups are born, while at the biggest, over 5,000 pups are born annually. In general grey seals are highly sensitive to disturbance by humans hence their preference for remote breeding sites. However, at one UK mainland colony at Donna Nook in Lincolnshire, seals have become habituated to human disturbance and over 70,000 people visit this colony during the breeding season with no apparent impact on the breeding seals.

UK grey seals breed in the autumn, but there is a clockwise cline in the mean birth date around the UK. The majority of pups in SW Britain are born between August and September, in north and west Scotland pupping occurs mainly between September and late November and eastern England pupping occurs mainly between early November to mid-December.

Female grey seals give birth to a single white coated pup which they suckle for 17 to 23 days. Pups moult their white natal coat (also called "lanugo") around the time of weaning and then remain on the breeding colony for up to two or three weeks before going to sea. Mating occurs at the end of lactation and then adult females depart to sea and provide no further parental care. In general, female grey seals return to the same colony to breed in successive years and often breed at the colony in which they were born. Grey seals have a polygynous breeding system, with dominant males monopolising access to females as they come into oestrus. The degree of polygyny varies regionally and in relation to the breeding habitat. Males breeding on dense, open colonies are more able to restrict access to a larger number of females (especially where they congregate around pools) than males breeding in sparse colonies or those with restricted breeding space, such as in caves or on cliff-backed beaches.

Harbour seals

Adult harbour seals typically weigh 80-100 kg. Males are slightly larger than females. Like grey seals, harbour seals are long-lived with individuals living up to 20-30 years.

Harbour seals normally feed within 40-50 km around their haul out sites. They take a wide variety of prey including sandeels, gadoids, herring and sprat, flatfish, octopus and squid. Diet varies seasonally and from region to region. Because of their smaller size, harbour seals eat less food than grey seals; 3-5 kg per seal per day depending on the prey species.

Harbour seals come ashore in sheltered waters, typically on sandbanks and in estuaries, but also in rocky areas. They give birth to their pups in June and July and moult in August. At these, as well as other times of the year, harbour seals haul out on land regularly in a pattern that is often related to the tidal cycle. Harbour seal pups are born having shed their white coat *in utero* and can swim almost immediately.

Harbour seals are found around the coasts of the North Atlantic and North Pacific from the subtropics to the Arctic. Five subspecies of harbour seal are recognized. The European subspecies, *Phoca vitulina vitulina*, ranges from northern France in the south, to Iceland in the west, to Svalbard in the north and to the Baltic Sea in the east. The largest population of harbour seals in Europe is in the Wadden Sea.

Approximately 30% of European harbour seals are found in the UK; this proportion has declined from approximately 40% in 2002. Harbour seals are widespread around the west coast of Scotland and throughout the Hebrides and Northern Isles. On the east coast, their distribution is more restricted with concentrations in the major estuaries of the Thames, The Wash, Firth of Tay and the Moray Firth. Scotland holds approximately 79% of the UK harbour seal population, with 16% in England and 5% in Northern Ireland.

The population along the east coast of England (mainly in The Wash) was reduced by 52% following the 1988 phocine distemper virus (PDV) epidemic. A second epidemic in 2002 resulted in a decline of 22% in The Wash, but had limited impact elsewhere in Britain. Counts in the Wash and eastern England did not demonstrate any recovery from the 2002 epidemic until 2009 but have increased dramatically in the past four years. In contrast, the adjacent European colonies in the Wadden Sea have experienced continuous rapid growth since 2002 but that increase may be slowing.

Major declines have now been documented in several harbour seal populations around Scotland, with declines since 2001 of 76% in Orkney, 30% in Shetland between 2000 and 2009, and 92% between 2002 and 2013 in the Firth of Tay. However the pattern of declines is not universal. The Moray Firth count declined by 50% before 2005 remained reasonably stable for 4 years then increased by 40% in 2010 and has fluctuated since. The Outer Hebrides apparently declined by 35% between 1996 and 2008 but the 2011 count was >50% higher than the 2008 count. The recorded declines are not thought to have been linked to the 2002 PDV epidemic that seems to have had little effect on harbour seals in Scotland.

Historical status

We have little information on the historical status of seals in UK waters. Remains have been found in some of the earliest human settlements in Scotland and they were routinely harvested for meat, skins and oil until the early 1900s. There are no reliable records of historical population size. Harbour seals were heavily exploited mainly for pup skins until the early 1970s in Shetland and The Wash. Grey seal pups were taken in Orkney until the early 1980s, partly for commercial exploitation and partly as a population control measure. Large scale culls of grey seals in the North Sea, Orkney and Hebrides were carried out in the 1960s and 1970s as population control measures.

Grey seal pup production monitoring started in the late 1950s and early 1960s and numbers have increased consistently since. However, in recent years, there has been a significant reduction in the rate of increase.

Boat surveys of harbour seals in Scotland in the 1970s showed numbers to be considerably lower than in the aerial surveys, which started in the late 1980s, but it is not possible to distinguish the apparent change in numbers from the effects of more efficient counting methods. After harvesting ended in the early 1970s, regular surveys of English harbour seal populations indicated a gradual recovery, punctuated by two major reductions due to PDV epidemics in 1988 and 2002 respectively.

Legislation protecting seals

The Grey Seal (Protection) Act, 1914, provided the first legal protection for any mammal in the UK because of a perception that seal populations were very low and there was a need to protect them. In the UK seals are protected under the Conservation of Seals Act 1970 (England, and Wales), the Marine (Scotland) Act 2010 and The Wildlife (Northern Ireland) Order 1985.

The Conservation of Seals Act prohibits taking seals during a close season (01/09 to 31/12 for grey seals and 01/06 to 31/08 for harbour seals) except under licence issued by the Marine Management Organisation (MMO). The Act also allows for specific Conservation Orders to extend the close season to protect vulnerable populations. After consultation with NERC, three such orders were established providing year round protection to grey and harbour seals on the east coast of England and in the Moray Firth and to harbour seals in the Outer Hebrides, Shetland, Orkney and the east coast of Scotland between Stonehaven and Dunbar (effectively protecting all the main concentrations of harbour seals along the east coasts of Scotland and England). The conservation orders in Scotland have been maintained under the Marine (Scotland) Act 2010.

The Marine (Scotland) Act 2010 (Section 6) prohibits the taking of seals except under licence. Licences can be granted for the protection of fisheries, for scientific and welfare reasons and for the protection of aquaculture activities. In addition, in Scotland it is now an offence to disturb seals at designated haulout sites. NERC (through SMRU) provides advice on all licence applications and haulout designations.

The Wildlife (Northern Ireland) Order 1985 provides complete protection for both grey and harbour seals and prohibits the killing of seals except under licence. In Northern Ireland it is an offence to intentionally or recklessly disturb seals at any haulout site.

Both grey and harbour seals are listed in Annex II of the EU Habitats Directive, requiring specific areas to be designated for their protection. To date, 16 Special Areas of Conservation (SACs) have been designated specifically for seals. Seals are features of qualifying interest in seven additional SACs. The SAC reporting cycle required formal status assessments for these sites and these were completed in 2013.

Questions from Marine Scotland, Department for Environment, Food and Rural Affairs and Natural Resources Wales.

Questions for SCOS 2014 were received from all three administrations (Marine Scotland, MS; Department for Environment, Food and Rural Affairs, Defra; Natural Resources Wales, NRW) and are listed in Annex II. Some of these questions were essentially the same, requiring regionally specific responses in addition to a UK wide perspective. These very similar questions were therefore amalgamated, with the relevant regional differences in response being given in the tables and text. The question numbers by administration are shown in the boxes for cross reference. The remaining questions were therefore regionally unique, requiring responses that focussed on the issue for a given area. The questions are grouped under topic headings, in the order and as they were given from the administrations.

In addition, Defra listed a number of secondary questions and asked if there was any additional information to *add* to the answers given in SCOS 2013. These are also listed under the relevant sections and, where appropriate, have been combined with similar questions from the other administrations. Where no new information is available, a summary of the current state of knowledge is shown in a text box.

Population dynamics

1. What are the latest estimates of the number of seals in UK waters?	MS Q1; Defra Q1; NRW Q1

Current status of British grey seals

Grey seal population trends are assessed from the counts of pups born during the autumn breeding season, when females congregate on land to give birth. Thus, regional differences in numbers do not reflect the abundance of animals in each region that might be observed at other times of the year.

The most recent surveys to estimate the UK grey seal pup production were carried out in 2012. These resulted in an estimate of 56,988 (95% CI 56,317, 57,683). Pup production estimates by location are given in Table 1. These are then converted to estimates of total population size (1+ aged population) using a mathematical model.

To estimate the total population size in 2013, the population dynamics model trajectories were projected forward and added to the estimated numbers of animals associated with the small number of non-surveyed breeding colonies to give an estimate 111,600 (95% CI 92,000-137,9000) UK grey seals (1+ aged population).

Table 1. ***Grey seal pup production estimates for the main colonies surveyed in 2012***.

Location	Pup production in 2012
England	**5,213**
Wales	**1,650**
Scotland	**50,025**
Northern Ireland	**100**
Total UK	**56,988**

Aerial surveys to estimate grey seal pup production were carried out in Scotland in 2012, using a new digital camera system. Details of the methods are given in SCOS-BP 14/01. Major colonies in Scotland are now surveyed biennially by air (see SCOS-BP14/01). Pup production is then converted to total population size (1+ aged population) using a mathematical model. The stages in the process (pup production → mathematical model → total population size) and the trends observed at each stage are given below.

Pup Production

Information on pup production at all major Scottish colonies has now been updated and the details are given in SCOS–BP 14/01. The total number of pups born in 2012 at all surveyed UK colonies was estimated to be 56,988 (95% CI 56,317, 57,683).

Regional estimates at surveyed colonies were 4,100 (95% CI 4,010, 4,190) in the Inner Hebrides, 14,100 (95% CI 13,615, 14,585) in the Outer Hebrides, 22,900 (95% CI 22,448, 23,352) in Orkney and 10,200 (95% CI 9,517, 10,883) at the North Sea colonies (including Isle of May, Fast Castle, Farne Islands, Donna Nook, Blakeney Point and Horsey/Winterton). A further 5,700 pups were estimated to have been born at other scattered colonies throughout Scotland, Northern Ireland, South-west England and Wales, producing a total UK pup production of 57,000.

Colonies on the east coast of England are monitored by the National Trust, Lincolnshire Trust for Natural History and Natural England. Numbers of pups born at these colonies continued to increase rapidly. Colonies in the southern North Sea increased by 10.5% between 2010 and 2012. Pup production at Donna Nook and East Anglia increased by 14.4% and those at the Farne Islands by 3.4% over the same period.

Trends in pup production

Details of the *trends* in pup production up to 2012 are presented in SCOS-BP 14/01. Briefly, this showed that there has been a continual increase in pup production since regular surveys began in the 1960s (Figure 1). In both the Inner and Outer Hebrides, the rate of increase declined in the early 1990s. Production was relatively constant since the mid-1990s but between 2010 and 2012 showed an annual increase of ~10 and ~5% respectively, the first substantial increase since the 1990s. And although the rate of increase in Orkney has declined since 2000, pup production also increased at an annual rate of ~6% between 2010 and 2012.

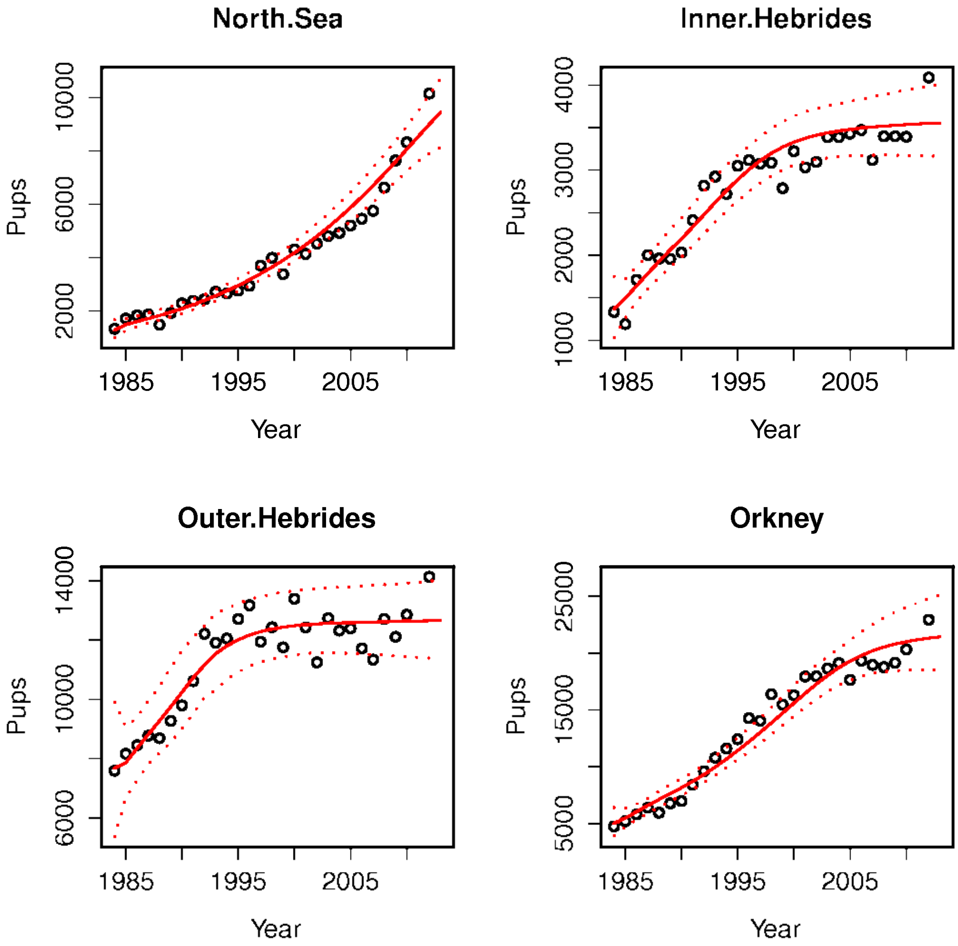

Figure 1. ***Mean estimates of pup production (solid lines) and 95% Confidence Intervals (dashed lines) from the model of grey seal population dynamics, fit to pup production estimates from 1984-2012 (circles) and a total population estimate from 2008.*** *Lines show the fit to pup production estimates plus the total population estimate.*

Pup production at colonies in the North Sea continues to increase exponentially. The increase has apparently slowed at the Farne Islands, but there is rapid expansion of newer colonies on the mainland coasts in Berwickshire, Lincolnshire, Norfolk and Suffolk. Interestingly, these colonies are all at easily accessible sites on the mainland where grey seals have probably never previously bred in significant numbers. Pup production in 2012 is shown in Table 2. These show an annual increase of between 2010 and 2012 with Donna Nook and East Anglia up by ~14% p.a. and the Farne Islands by ~3% p.a.

The most recent data for pup production in Wales remains the estimates for north Wales 2001-2002[1] at 110 pups, for Pembrokeshire 297 pups in 2005[2] and 260 pups born on Skomer Island in southeast Wales in 2011[3].

Table 2. ***Grey seal pup production estimates for the main colonies surveyed in 2012*** *compared to UK wide estimates for 2010.*

Location	Pup production in **2012**	Average annual change 2010 to **2012**	Pup production in 2010	Average annual change 2001 and 2006	Average annual change 2006 to **2012**
Inner Hebrides	4,088	+9.8%	3,391	+2.8%	+3.1%
Outer Hebrides	14,136	+4.9%	12,857	+0.1%	+3.3%
Orkney	22,926	+6.2%	20,312	+0.1%	+3.0%
Firth of Forth	5,210	+10.3%	4,279	+3.9%	+11.6%
Regularly monitored colonies in Scotland	46,360	+6.5%	40,839	+1.0%	+3.9%
Other Scottish colonies [1] (incl. Shetland & mainland)	3,665 [1]	+5.4%	3,299 [1]		
Total Scotland	**50,025**	+6.5%	**44,138**		
Donna Nook +East Anglia	3,360	+14.4%	2,566	+15.6%	+15.1%
Farne Islands	1,603	+3.4%	1,499	+0.7%	+5.1%
Annually monitored colonies in England	4,963	+10.5%	4,065	+7.0%	+11.2%
SW England (last surveyed 1994)[3]	250 [3]		250 [3]		
Wales [2,3]	1,650 [3]		1,650 [3]		
Total England & Wales	**6,863**	**+7.3%**	**5,965**		
Northern Ireland[3]	100 [3]		100 [3]		
Total UK	**56,988**	**+6.5%**	**50,203**		

1 Estimates derived from data collected in different years
2 Multiplier derived from indicator colonies surveyed in 2004 and 2005 and applied to other colonies last monitored in 1994
3 Esimated production for colonies that are rarely monitored

1 http://biosciences.exeter.ac.uk/media/universityofexeter/schoolofbiosciences/pdfs/pgrstudentpublications/CCW_MMR_NO05.pdf
2 Strong P.G., Lerwill J., Morris S.R., and Stringell, T.B. (2006) Pembrokeshire marine SAC grey seal monitoring 2005. CCW Marine Monitoring Report No: 26; unabridged version (restricted under licence). 54pp.
3 http://wtswwcdn.8a1bc20d.cdn.memsites.com/wp-content/uploads/2011/05/2011-Skomer-Seal-Report-final.pdf

Population size

Converting pup counts from air surveys into a total population size requires a number of steps as shown in Figure 2.

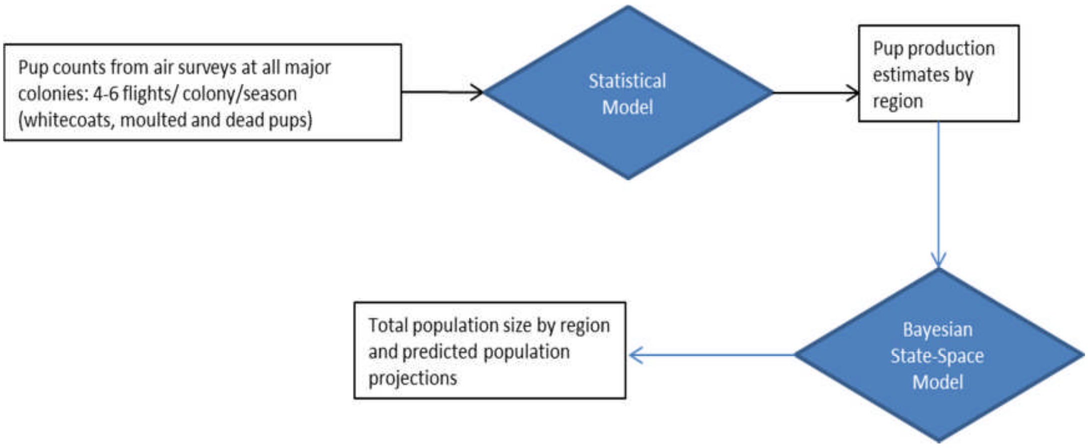

Figure 2. ***Schematic diagram of steps involved in estimating total population size from pup counts*** *(see also SCOS BP-09/02, SCOS BP-10/02).*

Using appropriate estimates of age-specific fecundity rates and both pup and non-pup survival rates we can convert pup production estimates into estimates of total population size. The estimate of total population alive at the start of the breeding season depends critically on the estimates of these rates. We use a Bayesian state-space population dynamics model to estimate these rates.

Until the late 1990s all the regional populations grew exponentially, implying that the demographic parameters were, on average, constant over the period of data collection. Thus, estimates of the demographic parameters were available from a simple population model fitted to the entire pup production time series.

Some combination of reductions in the reproductive rate or the survival rates of pups, juveniles and adults (SCOS-BP 09/02, 10/02 and 11/02) has resulted in reduced population growth rates in the Northern and Western Isles. Fitting the model of grey seal population dynamics with density dependence acting through either fecundity or pup survival showed that the time series of pup production estimates did not contain sufficient information to allow us to quantify the relative contributions of these factors (SCOS-BP 06/07, 09/02). In 2010 and 2011, we incorporated additional information in the form of an independent estimate of population size based on counts of the numbers of grey seals hauled out during the summer and information on their haulout behaviour (SCOS-BP 10/04 and 11/06). Inclusion of the independent estimate allowed us to reject the models that assumed density dependent effects operated through fecundity and all estimates are therefore based on a model incorporating density dependent pup survival.

In 2012, SCOS discussed the priors on the model input parameters in some detail, following re-examination of the data being used and the differences made to the population estimates by changing a number of them to less informative priors (SCOS-BP 12/01 and SCOS-BP 12/02). This year SCOS decided to use the results from a model run using these revised priors (SCOS-BP 12/02) and incorporating a prior based on a distribution for the ratio of males to females in the population (see SCOS-BP 14/02 for details) and the independent estimate of total population size from the summer surveys.

Work on updating the priors is still in progress. A re-analysis of all the combined data available from pup tagging studies (hat tags, phone tags and GPS/GSM tags) will improve our estimates of sex-specific first year pup survival. Updated estimates of adult female survival and fecundity will be derived from the long term studies at North Rona and the Isle of May (further details on the updated estimates are also given in response to Question 2 below).

Thus, the estimated total grey seal population size associated with all regularly monitored colonies in 2013 was 98,800 (95% CI 81,400-122,000) for the model incorporating density dependent pup survival, using the revised priors and including the independent estimate (details of this analysis are given in SCOS-BP 14/02). A comprehensive survey of data available from the less frequently monitored colonies was presented in SCOS BP 11/01. Total pup production at these sites was updated in 2013 (SCOS-BP 14/02) and estimated to be approximately 5,670. The total population associated with these sites was then estimated using the average ratio of pup production to population size for all annually monitored sites derived from the pup survival model. Confidence intervals were estimated by assuming that they were proportionally similar to the pup survival model confidence intervals. This produced a population estimate for these sites of 12,800 (approximate 95% CI 10,600 to 15,900). Combining this with the annually monitored sites gives an estimated 2013 UK grey seal population of 111,600 (95% CI 92,000-137,900).

This is approximately the same as the estimate reported in 2012, despite an increase in the pup production. The pup counts have increased in the last two surveys, which has resulted in a lack of fit of the model to the pup production estimates in recent years. In addition, the estimated adult survival rate from the model was very high and the maximum pup survival rate was very low, which suggests some other parameters, such as inter-annual variation in fecundity could be causing a mismatch between the estimates from the model and the pup production data. This will be investigated further at SCOS in 2015.

Population trends

Model selection criteria suggest that density dependence is acting mainly on pup survival. The independent population estimate is consistent with this conclusion. This also implies that the overall population will closely track the pup production estimates when experiencing density dependent control as well as during exponential growth. It is therefore likely that the total populations of grey seals in the Hebrides and Orkney will have followed similar trajectories to those shown by the time series of pup productions and will have increased little over recent years. Conversely, the North Sea population is thought to still be growing exponentially. Further details on these trends are given in SCOS-BP 14/01.

UK grey seal population in a world context

The UK grey seal population represents approximately 44% of the world population on the basis of pup production. The other major populations in the Baltic and the western Atlantic are also increasing, but at a faster rate than in the UK (Table 3). If the difference in growth rate is due to reduced pup survival in the UK population compared to the Baltic and the western Atlantic, the UK will hold less than 44% of the total all age population.

*Table 3. **Relative sizes of grey seal populations**. Pup production estimates are generally used because of the uncertainty in overall population estimates*

Region	Pup Production	Year	Possible population trend[2]
UK	**57,000**	2012	Increasing
Ireland	1,600	2005	Unknown[1]
Wadden Sea	430	2012[3]	Increasing [2]
Norway	1,300	2008	Increasing[4]
Russia	800	1994	Unknown[2]
Iceland	1,200	2002	Declining[2]
Baltic	4,700	2007	Increasing[2,5]
Europe excluding UK	**10,030**		Increasing
Canada - Sable Island	62,000	2010	Increasing[6]
Canada - Gulf St Lawrence + Eastern Shore Canada	14,200	2010	Declining[7]
USA	2,600	2008	Increasing[8]
WORLD TOTAL	**129,000**		Increasing

[1] Ó Cadhla, O., Strong, D., O'Keeffe, C., Coleman, M., Cronin, M., Duck, C., Murray, T., Dower, P., Nairn, R., Murphy, P., Smiddy, P., Saich, C., Lyons, D. & Hiby, A.R. 2007. An assessment of the breeding population of grey seals in the Republic of Ireland, 2005. Irish Wildlife Manuals No. 34. National Parks & Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.
[2]Data summarised in:- Grey seals of the North Atlantic and the Baltic. 2007. Eds: T. Haug, M. Hammill & D. Olafsdottir. NAMMCO Scientific Publications, Vol. 6.
[3] Brasseur, S., Borchardt, T., Czeck, R., Jensen, L.F., Galatius, A., Ramdohr, S., Siebert, U., Teilmann, J., 2012, Aerial surveys of Grey Seals in the Wadden Sea in the season of 2011-2012 - Increase in Wadden Sea grey seals continued in 2012. Trilateral Seal Expert Group.
[4] Øigård, T.A., Frie, A.K., Nilssen, K.T., Hammill, M.O., 2012, Modelling the abundance of grey seals (*Halichoerus grypus*) along the Norwegian coast. ICES Journal of Marine Science: Journal du Conseil, 69(8) 1436-1447.
[5] Baltic pup production estimate based on mark recapture estimate of total population size and an assumed multiplier of 4.7 HELCOM fact sheets (www.HELCOM.fi)
[6] Bowen, W.D., McMillan,J.I. & Blanchard, W. 2007. Reduced Population Growth Of Gray Seals At Sable Island: Evidence From Pup Production And Age Of Primiparity. Marine Mammal Science, 23(1): 48–64
[7] Thomas,L.,Hammill,M.O. & Bowen,W.D. 2011 Estimated size of the Northwest Atlantic grey seal population 1977-2010 Canadian Science Advisory Secretariat: Research Document 2011/17 pp27.
[8]NOAA (2009) http://www.nefsc.noaa.gov/publications/tm/tm219/184_GRSE.pdf

Current status of British harbour seals

Harbour seals are counted while they are on land during their August moult, giving a minimum estimate of population size. Not all areas are counted every year but the aim is to cover the UK coast every 5 years.

Combining the most recent counts (2007-2013) gives a total of 26,290 counted in the UK. Scaling this by the estimated proportion hauled out produced an estimated total population for the UK in 2013 of 36,500 (approximate 95% CI 29,900 – 49,700).

Harbour seal counts were stable or increasing until around 2000 when declines were seen in Shetland (which declined by 30% between 2000-2009), Orkney (down 78% between 2000-2013) and the Firth of Tay (down 93% between 2000-2013). However, other regions have been largely continually stable (west coast of Highland region and the Outer Hebrides). Counts along the English east coast were very similar to those reported in 2012.

The most recent minimum population estimates by region are given in Table 4.

Table 4. ***Minimum estimates of the UK harbour seal populations.***

Location	Most recent count (2007-2013)
England	4,622
Wales	0[1]
Scotland	20,720
Northern Ireland	948
Total UK	**26,290**

[1] There are no established harbour seal haul out sites in Wales

Each year SMRU carries out surveys of harbour seals during the moult in August. Recent survey counts and overall estimates are summarised in SCOS-BP 14/03. Given length of coastline it is impractical to survey the whole coastline every year and SMRU aims to survey the whole coastline across 5 consecutive years. However, in response to the observed declines around the UK the survey effort has been increased. The majority of the English and Scottish east coast populations are surveyed annually.

Seals spend the largest proportion of their time on land during the moult and they are therefore visible during this period to be counted in the surveys. Most regions are surveyed by a method using thermographic aerial photography to identify seals along the coastline. However, conventional photography is used to survey populations in the estuaries of the English and Scottish east coasts.

The estimated number of seals in a population based on these methods contains considerable levels of uncertainty. A large contribution to uncertainty is the proportion of seals not counted during the survey because they are in the water. We cannot be certain what this proportion is, but it is known to vary in relation to factors such as the time of year, the state of the tide and the weather. Efforts are made to reduce the effect of these factors by standardising the time of year and weather conditions and always conducting surveys within 2 hours of low tide.

Main Advice

The most recent counts of harbour seals by region are given in Table 5 and Figure 3. These are minimum estimates of the British harbour seal population. Results of surveys conducted in 2013 are described in more detail in SCOS-BP 14/03. It has not been possible to conduct a synoptic survey of the entire UK coast in any one year. Data from different years have therefore been grouped into recent, previous and earlier counts to illustrate, and allow comparison of, the general trends across regions.

Combining the most recent counts (2007-2013) at all sites, approximately 26,290 harbour seals were counted in the UK: 79% in Scotland; 18% in England; 3% in Northern Ireland (Table 5). Including the 3,500 seals counted in the Republic of Ireland produces a total count of ~29,800 harbour seals for the British Islands.

Apart from the population in The Wash, harbour seal populations in the UK were relatively unaffected by PDV in 1988. The overall effect of the 2002 PDV epidemic on the UK population was even less pronounced. However, again the English east coast populations were most affected. Counts from 2002 to 2008 did not indicate a recovery in The Wash population following the epidemic. From 2008 to 2010 the counts increased by around 40%. Since then numbers have been relatively stable and the 2013 count was very similar to that reported in 2012.

Table 5. ***The most recent August counts of harbour seals at haul-out sites in Britain and Ireland by seal management unit compared with two previous periods, in 1996 and 1997 and between 2000 and 2006.*** *Values that have been updated with 2013 counts are highlighted with a grey background.*

Seal Management Unit / Country		Harbour seal counts					
		2007-2013		2000-2006		1996-1997	
1 Southwest Scotland		834	(2007)	623	(2005)	929	(1996)
2a West Scotland - South		5,915	(2007; 2009)	7,003	(2000; 2005)	5,651	(1996)
2b West Scotland - Central		4,004	(2007; 2008)	3,956	(2005)	2,700	(1996)
2c West Scotland - North		1,138	(2008; 2013)	709	(2005)	460	(1996-1997)
2 West Scotland	a	11,057	(2007-2009; 2013)	11,668	(2000; 2005)	8,811	(1996-1997)
3 Western Isles		2,739	(2011)	1,981	(2003; 2006)	2,820	(1996)
4a North Coast		73	(2013)	146	(2005-2006)	265	(1997)
4b Orkney		1,865	(2013)	4,238	(2006)	8,522	(1997)
4 North Coast & Orkney		1,938	(2013)	4,384	(2005-2006)	8,787	(1997)
5 Shetland		3,039	(2009)	3,038	(2006)	5,994	(1997)
6 Moray Firth		898	(2008; 2011; 2013)	1,028	(2005-2006)	1,409	(1997)
7 East Scotland		215	(2007; 2013)	667	(2005-2006)	764	(1997)
SCOTLAND TOTAL		**20,720**	(2007-2009; 2011; 2013)	**23,389**	(2000; 2003; 2005-2006)	**29,514**	(1996-1997)
8 Northeast England	b	83	(2008; 2013)	* 62	(2005-2006)	* 54	(1997)
9 Southeast England	c	4,504	(2013)	2,964	(2005-2006)	3,222	(1995; 1997)
10 West England & Wales	d	35	(estimate)	20	(estimate)	15	(estimate)
ENGLAND & WALES TOTAL		**4,622**	(2008; 2013)	**3,046**	(2005-2006)	**3,291**	(1995; 1997)
BRITAIN TOTAL		**25,342**	(2007-2009; 2011; 2013)	**26,435**	(2000; 2003; 2005-2006)	**32,805**	(1995-1997)
NORTHERN IRELAND TOTAL	e	**948**	(2011)	**1,176**	(2002; 2006)		
UK TOTAL		**26,290**	(2007-2009; 2011; 2013)	**27,611**	(2000; 2002-2003; 2005-2006)		

SOURCES - Most counts were obtained from aerial surveys conducted by SMRU and were funded by Scottish Natural Heritage (SNH) and the Natural Environment Research Council (NERC). Exceptions are:

[a] Part of the West Scotland survey in 2009 funded by Scottish Power.

[b] The Tees data collected and provided by the Industry Nature Conservation Association (Woods, 2013). The 2008 survey from Coquet Island to Berwick funded by the Department of Energy and Climate Change (DECC, previously DTI).

[c] Essex & Kent data for 2013 collected and provided by the Zoological Society London (Barker *et al*., 2014).

[d] No dedicated harbour seal surveys in this management unit and only sparse info available. Estimates compiled from counts shared by other organisations (Chichester Harbour Conservancy) or found in various reports & on websites (Boyle, 2012; Hilbrebirdobs.blogspot.co.uk, 2012, 2013; Sayer, 2010a, 2010b, 2011; Sayer *et al.,* 2012; Westcott, 2002). Apparent increases may partly be due to increased reporting and improved species identification.

[e] Surveys carried out by SMRU and funded by Northern Ireland Environment Agency (NIEA) in 2002 & 2011 (Duck, 2006; Duck & Morris, 2012) and Marine Current Turbines Ltd in 2006-2008 & 2010 (SMRU Ltd, 2010).

*Northumberland coast south of Farne Islands not surveyed in 2005 & 1997, but no harbour seal sites known here.

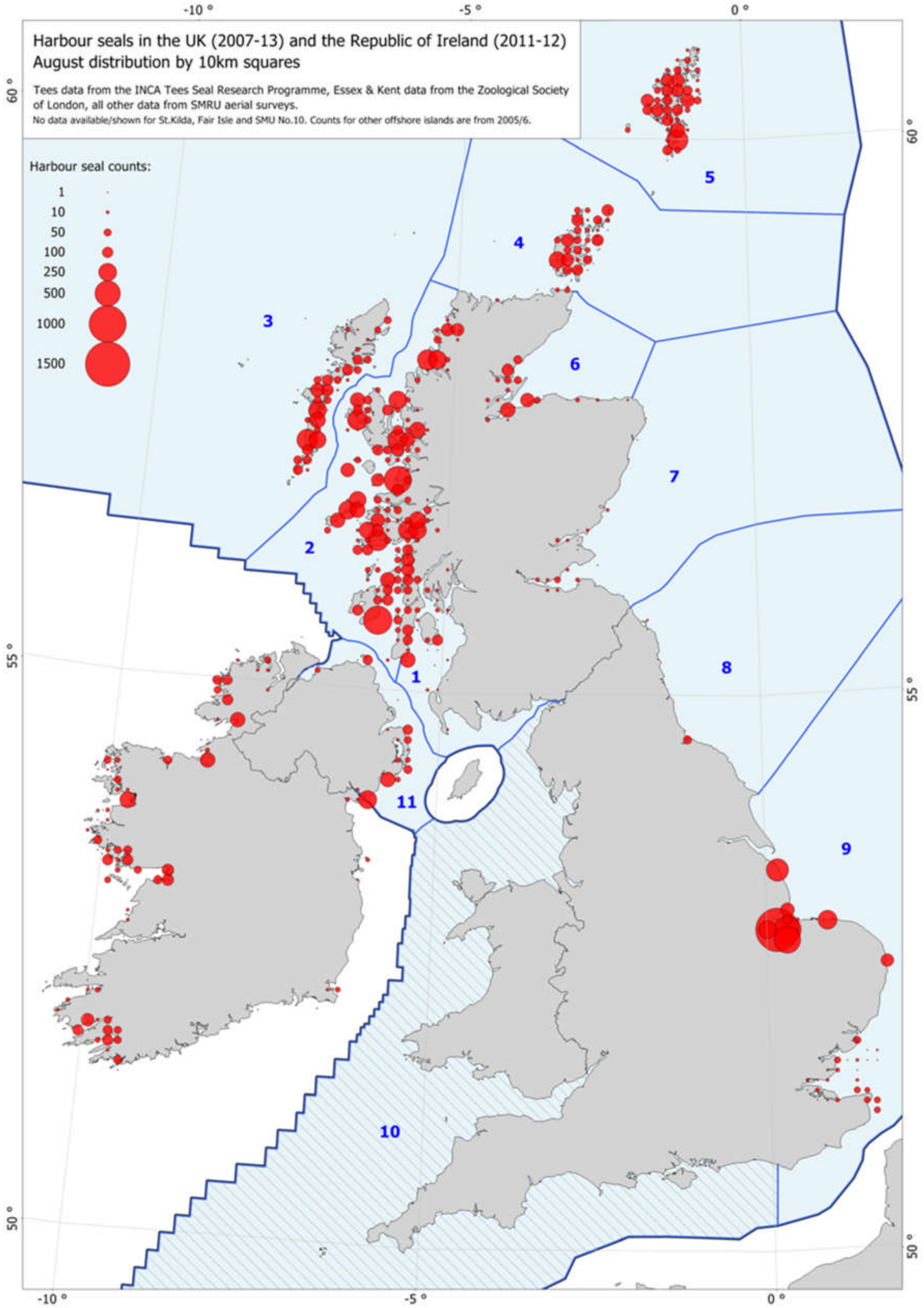

Figure 3. ***August distribution of harbour seals around the British Isles.*** *Very small numbers of harbour seals (<50) are anecdotally but increasingly reported for the West England & Wales management unit, but are not included on this map*

Population trends

As reported in SCOS 2008 to 2013, there have been general declines in counts of harbour seals in several regions around Scotland and details are given in SCOS-BP 14/03

In Orkney, the new low of 1,865, counted in August 2013, is 76% lower than the last relatively high count recorded in 2001 (7,752). This is equivalent to an average annual decline of approximately 11%, and indicates that the decline first identified in 2006 is continuing at a fairly consistent rate.

In the Moray Firth there is considerable variability in the August total counts for the entire region and since 2007 no clear overall trend is evident.

The 2013 harbour seal moult count for the Firth of Tay and Eden Estuary Special Area of Conservation (SAC) (50) was 43% lower than the 2012 count of 88 (SCOS-BP 14/03). The 2013 count is a new all-time low for this harbour seal SAC and represents only 8% of the mean from counts between 1990 and 2002 (641). Harbour seals in this area are of sufficient concern that Marine Scotland has not issued any licences to shoot harbour seals within the East Scotland Management Area since 2010.

The combined counts for the Southeast England management unit in 2013 (4,504) was very similar to the previous equivalent count (4,568 combination from 2010 and 2012). Although the Southeast England population has returned to its pre-2002 epidemic levels, it is still lagging behind the rapid recovery of the harbour seal population in the Wadden Sea where counts have increased from 10,800 in 2003 to 26,788 in 2013, equivalent to an average annual growth rate of 9.5% over the last ten years.

UK harbour seal populations in a European context

The UK harbour seal population represents approximately 30% of the eastern Atlantic sub-species of harbour seal (Table 6). The declines in Scotland mean that the relative importance of the UK population will probably decline.

*Table 6. **Size and status of European populations of harbour seals.** Data are counts of seals hauled out during the moult.*

Region	Number of seals counted[1]	Years when latest data was obtained
Scotland	**20,720**	2007-2013
England	**4,620**	2012
Northern Ireland	**950**	2011
UK	**26,290**	
Ireland	3,500	2011-12
Wadden Sea-Germany	15,700	2012
Wadden Sea-NL	6,500	2012
Wadden Sea-Denmark	4,000	2012
Lijmfjorden-Denmark	1,050	2008
Kattegat/Skagerrak	11,700	2007
West Baltic	750	2008
East Baltic	600	2008
Norway	7,080	2013
Iceland	11,000	2011
Barents Sea	1,900	2010
Europe excluding UK	**62,800**	
Total	**89,050**	

[1] counts rounded to the nearest 100. They are minimum estimates of population size as they do not account for proportion at sea and in many cases are amalgamations of several surveys.

Data sources: ICES Report of the Working Group on Marine Mammal Ecology 2004; Desportes,G., Bjorge,A., Aqqalu, R-A and Waring,G.T. (2010) Harbour seals in the North Atlantic and the Baltic. NAMMCO Scientific publications Volume 8.; Nilssen K, 2011. Seals – Grey and harbour seals. In: Agnalt A-L, Fossum P, Hauge M, Mangor-Jensen A, Ottersen G, Røttingen I,Sundet JH, and Sunnset BH. (eds). Havforskningsrapporten 2011. Fisken og havet, 2011(1).; Härkönen,H. and Isakson,E. 2010. Status of the harbor seal (*Phoca vitulina*) in the Baltic Proper. NAMMCO Sci Pub 8:71-76.; Olsen MT, Andersen SM, Teilmann J, Dietz R, Edren SMC, Linnet A,. and Härkönen T. 2010. Status of the harbour seal (*Phoca vitulina*) in Southern Scandinavia. NAMMCO Sci Publ 8: 77-94.; http://www.waddensea-worldheritage.org/news/2012-10-31-seal-count-2012-more-seals-ever-wadden-sea; http://www.fisheries.is/main-species/marine-mammals/stock-status/; http://www.nefsc.noaa.gov/publications/tm/tm213/pdfs/F2009HASE.pdf http://www.nammco.no/webcronize/images/Nammco/976.pdf, Nilssen K and Bjørge A 2014. Seals – grey and harbor seals. In: Bakketeig IE, Gjøsæter H, Hauge M, Sunnset BH and Toft KØ (eds). Havforskningsrapporten 2014. Fisken og havet, 2014(1).

2. What is known about the population structure, including survival and age structure of grey and common seals in UK and European waters? Are there likely to be any substantial regional differences in grey seal demographics?	MS Q2; Defra Q2; NRW Q2 and Q3

Grey seals

There is evidence for regional differences in grey seal demographics but information on vital rates would improve our ability to provide advice on population status. This includes the requirement for a time series of fecundity and survival rates on a regional basis.

The only contemporary data that we have on fecundity and adult survival has been estimated for adult females at the two breeding colonies which constitute the long term studies (see survival and fecundity rates below)

Age and sex structure

While the population was growing at a constant rate, i.e. a constant exponential change in pup production, the stable age structure for the female population could be calculated from the population dynamics model. However, since the mid-1990s this has not been possible since changes in pup production growth rates imply changes in age structure. In the absence of a population wide sample or a robust means of identifying age-specific changes in survival or fecundity, we are unable to accurately estimate the age structure of the female population. The only data on age structure for UK grey seals that exists was from samples of shot animals and this has not been updated.

Survival and fecundity rates

Survival rates and fecundity estimates for adult females breeding at North Rona and the Isle of May have been estimated from re-sightings of permanently marked animals. An integrated analysis of resightings, post-partum mass and reproductive success using data collected from 1987 to 2012 was used to explore the relationship between mass and probability of breeding (individual fecundity). Results suggest differences between the Isle of May and North Rona where pup production trajectories are markedly different (increasing at the Isle of May, declining at North Rona). Overall fecundity estimates differed between sites with a general estimate of 0.77 (0.750, 0.792 95% Bayesian credible intervals) for North Rona and 0.86 (0.835, 0.882 95% Bayesian credible intervals) for the Isle of May (For more details see SCOS-BP 14/04). These estimates are lower than previous estimates for UK grey seals of 0.94 for the Farne Islands but are comparable to the estimate of 0.83 for the Hebrides[4].

Adult survival (averaged over all years) at the Isle of May was not related to mass and was estimated to be generally high 0.926 (95% Bayesian credible interval 0.792, 0.977). At North Rona annual survival rates were estimated to be 0.936 (95% Bayesian credible interval 0.904, 0.961). There was no evidence of mass dependent survival, but there was annual variation in mass gain at the Isle of May. However at North Rona there appeared to be stronger evidence for a negative relationship between mass and survival. For more details see SCOS-BP 14/04.

Given the importance of estimating fecundity in grey seals across regions, SCOS 2013 recommended a workshop be held to discuss the various empirical options and best methods for collecting data that would provide these estimates. The workshop was held at SMRU in May 2014. The outcomes need to be refined and prioritised and will then be taken forward for future funding.

Regional differences in grey seal demographics and genetics

The difference in population trends between regions for UK grey seals suggests underlying regional differences in demographics. For example, a recent study of grey seals in the Baltic Sea[5] indicated that demographic structure changed with different population trends and changes in adult female and juvenile survival for the population on Sable Island in Canada were found when two five year periods were compared[6].

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[4] Boyd, I. L. (1985). Pregnancy and ovulation rates in grey seals (*Halichoerus grypus*) on the British coast. Journal of Zoology 205(A), 265-272.

[5] Kauhala, KI, Ahola, MP and Kunnasranta, M (2012). Demographic structure and mortality rate of a Baltic grey seal population at different stages of population changes, judged on the basis of the hunting bag in Finland. Ann. Zool. Fennici. 49: 287-305

[6] Den Heyer, CE, Bowen, WD, and McMillan, JJ. 2014. Long term changes in grey seal vital rates at Sable Island estimated from POPAN mark-resighting analysis of branded seals. DFO Can. Sci. Advis. Sec. Res. Doc 2013/021. V + 21p

Harbour seals

Knowledge of UK harbour seal demographic parameters (i.e. vital rates) is limited and therefore inferences about the population dynamics rely largely on count data from moulting surveys. Information on vital rates would improve our ability to provide advice on population status.

Age and sex structure

The absence of any extensive historical cull data or a detailed time series of pup production estimates means that there are no reliable data on age structure of the UK harbour seal populations. Although seals found dead during the PDV epidemics in 1988 and 2002 were aged, these were clearly biased samples that cannot be used to generate population age structures.

Survival and fecundity rates

Survival estimates among adult UK harbour seals from photo-ID studies carried out in NE Scotland have been published[7],[8]. This resulted in estimates of 0.95 (95% CI 0.91-0.97) for females and 0.92 (0.83-0.96) for males.

A study investigating survival in first year harbour seal pups using telemetry tags was carried out by SMRU in Orkney and on Lismore in 2007. Survival was not significantly different between the two regions and expected survival to 200 days was very low at only 0.3[9].

3. Is there any [new] evidence of populations or subpopulations specific to local areas in UK waters? Is there any evidence of population structuring specifically through genetic differentiation or stable isotope profiles among seals in Welsh waters, the West England and Wales Management Unit (MU) and the rest of NE European waters?	MS Q2; Defra Q3; NRW Q3 and Q4

A recent publication on the genetic population structure of the Western and Eastern Atlantic and Baltic grey seal populations[10] indicated strong population structure and gene flow with Orkney being the source of emigrants to other areas of the Eastern Atlantic.

Grey Seals

Data on differences in genetic population structure between regions is not synonymous with Management Units. Therefore care needs to be taken for genetic data to be used in the context of differentiating Management Units.

Harbour Seals

Re-analysis of the SMRU harbour seal genetic dataset (n=254) using microsatellite markers is currently being carried out. Further results on this will be reported to SCOS 2015.

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[7] Cordes, LS., Thompson, PM (2014). Mark-recapture modelling accounts for state uncertainty provides concurrent estimates of survival and fecundity in a protected harbor seal population Marine Mammal Science 30(2), 691-705.

[8] Mackey, BL., Durban, JW., Middlemas, SJ., Thompson PM (2008). A Bayesian estimate of harbour seal survival using sparse photo-identification data Journal of Zoology, 274; 18-27

[9] Hanson, N., Thompson, D., Duck, C., Moss, S., Lonergan, M. (2013). Pup mortality in a rapidly declining harbour seal (*Phoca vitulina*) population. PLoS One, 8, e80727.

[10] Klimova, A, Phillips CD, Fietz, K, Olsen, MT, Harwood J, Amos, W and Hoffman, JI (2104) Global population structure and demographic history of the grey seal. Molecular Ecology, 23(16): 3999-4017.

4. Have there been any recent developments in relation to non-lethal methods of population control, which mean that they could now effectively be applied to English seal populations where appropriate?	Defra Q5;

There have been no specific developments in this area and therefore no new information to add (see SCOS Advice 2013).

5. What are the latest results from satellite tagging in respect of usage of specific coast and marine areas around England by grey and common seals and whether or not these suggest potential foraging sites? And what is the latest information on seal movements (satellite tracking or photo ID) between colonies in Wales, the West England and Wales Management Unit, other regions in the UK, Ireland and France?	Defra Q6; NRW Q5

There have been no specific developments in this area (see SCOS Advice 2013) but a model to assign activity budgets for grey seals has now been published[11].

Grey and Harbour seal movements - telemetry

Grey and harbour seals have not been telemetry tagged in England or Wales since 2010 and 2012, respectively. Thus the most recent information is available in SCOS 2013 (Question 5, Figure 7).

As scheduled in SCOS 2013, a state-space model which assigns dive and movement behaviours into foraging, travelling and resting has been developed under funding from DECC and Scottish Government. It has been run for the SMRU holdings of grey and harbour seal telemetry data. The method and results are described in two papers[11],[12]. It has also been utilised to infer that some individuals forage at anthropogenic structures[13].

Movements between France and England by seals tagged in France were reported last year (SCOS 2013, Question 5). There have been movements by grey seals tagged in South East Ireland to Wales, Isle of Man and Western Scotland (M.Cronin, pers comm.). In 2014, a grey seal tagged in North West Netherlands travelled to the Farnes and another to Orkney and back. In addition, a harbour seal tagged in South West Netherlands travelled to The Wash (S. Brasseur, pers comm.).

Grey seal movements - photo-ID

A collaborative study between Natural Resources Wales (NRW) and SMRU is investigating adult female grey seal movements and connectivity between sites using repeated photographic surveys of animals at different sites to add to existing material to build up a capture-mark-recapture database. This studentship is due to complete in 2017.

Grey seal at-sea usage

Maps showing the at-sea usage by both grey and harbour seals across the UK (combining telemetry data with aerial survey counts at haul out sites to give a population level mean usage with

[11] McClintock, BT , Russell, DJF , Matthiopoulos, J & King, R (2013).'Combining individual animal movement and ancillary biotelemetry data to investigate population-level activity budgets'' Ecology, 94:838-849.
[12] Russell, DJF, Matthiopoulos J., Thompson, PM, Thompson, D, Hammond P., Jones, E, Mackenzie, M., Moss S., & McConnell, B. Comparative influence of intrinsic and extrinsic drivers on activity budgets in sympatric grey and habour seals. Oikos, in review.
[13] Russell, DJF , Brasseur, S , Thompson, D , Hastie, GD , Janik, VM , Aarts, G , McClintock, BT , Matthiopoulos, J , Moss, S & McConnell, BJ (2014). Marine mammals trace anthropogenic structures at sea. Current Biology, 24:R638-R639.

confidence intervals) are available at
http://www.scotland.gov.uk/Topics/marine/science/MSInteractive/Themes/usage.

6. Is there any evidence that seals move between protected sites (e.g. SACs, SSSIs) and have any routine movement passages been identified?	NRW Q6

There is evidence that both grey and harbour seals move between protected sites but routine passages are more difficult to identify.

There are some movements between protected sites. Here we have examined movements of seals between Special Areas of Conservation. We have defined individuals as being at an SAC site if a part of their tracks is within the area defined as per JNCC (http://jncc.defra.gov.uk/default.aspx?page=5201&LAYERS=TwelveTS, UKCS, EEZ, SAC).

Such movements are much more prevalent in grey seals. However, from the telemetry data we have found movements of harbour seals between the neighbouring SACs in Northern Ireland (Strangford Lough and Murlough; Figure 4). Furthermore, we also observed one individual tagged in Skye using both the Skye (Ascrib, Isay and Dunvegan) and Sound of Barra SACs.

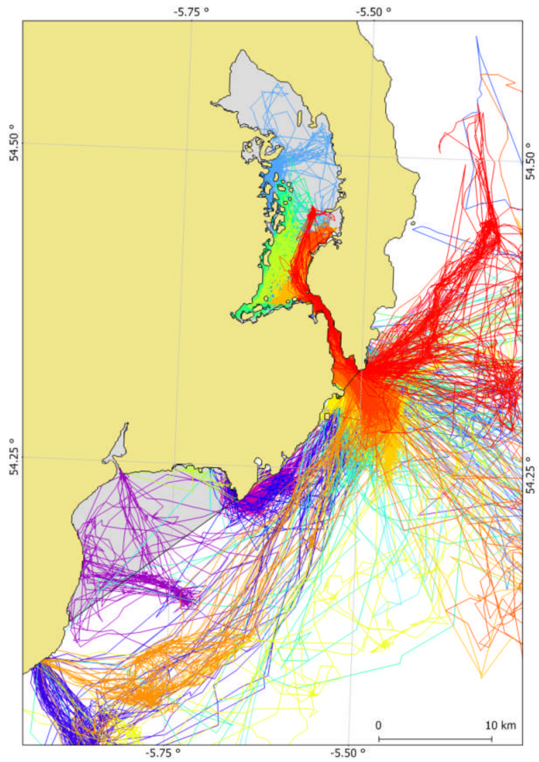

Figure 4. ***The tracks of 33 harbour seals tagged in Strangford Lough SAC in 2006, 2008 and 2010.*** *The most northern grey area is Strangford Lough SAC and the lower grey area is Murlough SAC.*

In adult grey seals, there is substantial movement between some SACs (Figure 5). This movement is particularly prevalent between the Isle of May and Berwickshire and North Northumberland Coast

SAC which encompasses the Farnes. Some of these movements are associated with individuals moving to other haul outs to breed[14].

Grey seal pups have been tagged on 5 SACs: Pembrokeshire Marine, Lleyn Peninsula and the Sarnau, Monach Islands, Isle of May, and Berwickshire and North Northumberland Coast. Pups tagged on the Monach Islands did not travel to any other grey seal SACs during the life time of the telemetry tags (<1 year). However, pups tagged at the other four SACs did travel to other SACs (Figure 5).

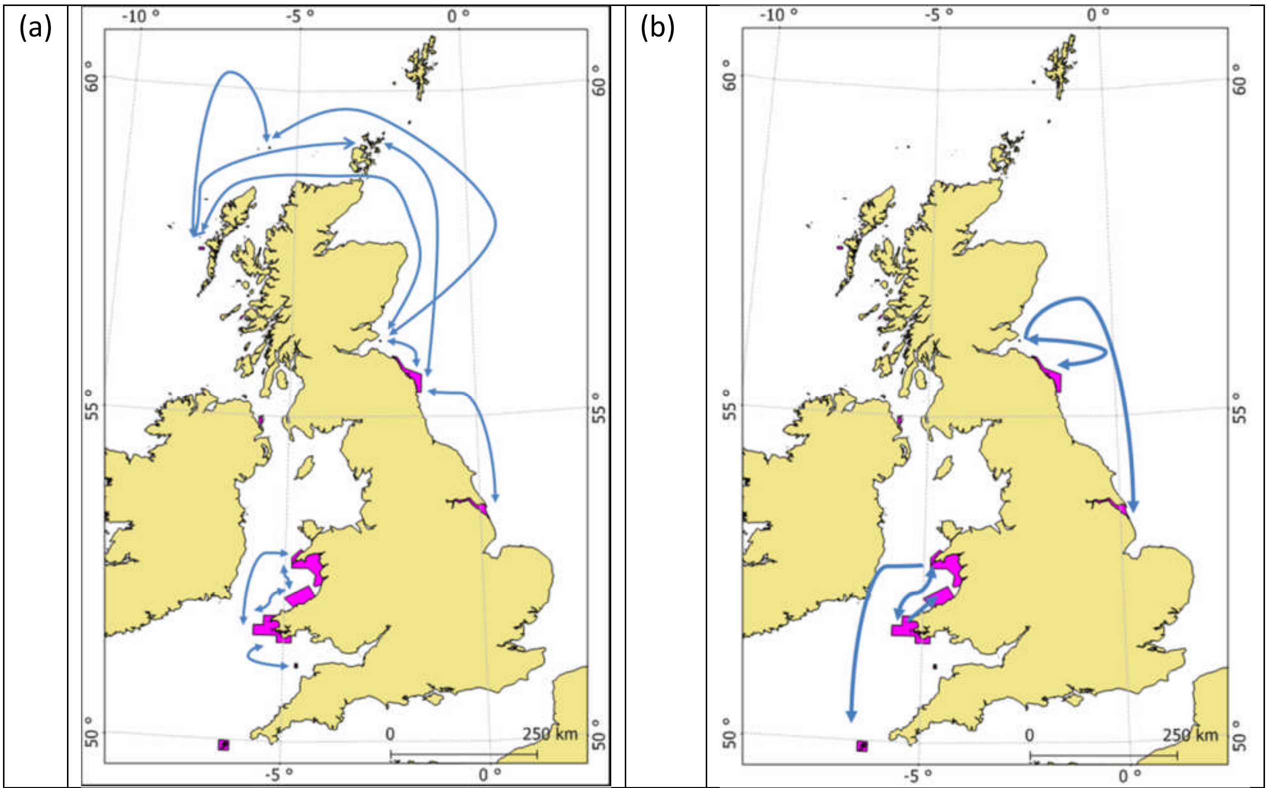

Figure 5. ***The movements of grey seal adults (a) and pups (b) between SACs (for which grey seals are primary or qualifying features).*** *For adults the arrows simply show movements but not their direction. For pups, the arrows start from the tagging location. Pups returning to the SAC on which they were born were not included.*

7. What are the median, mean, maximum and 95% CIs of travel distances of grey seals that have been satellite tracked in the West England and Wales management unit (MU) and surrounding waters? Such distance metrics might be used, within each MU, to provide distances within which SACs and developments should be considered for impact assessments	NRW Q7

The median, mean, maximum and 95% confidence intervals of travel distances of grey seals tagged in Wales are given.

Analysis

In response to the question - what are the distance statistics of trips from given haulout sites (regardless of where the trip ends)? - the following pilot analysis was carried out. The aim is to

[14] Russell, DJ., McConnell, BJ., Thompson, D., Duck, CD., Morris, C., Harwood, J. and Matthiopoulos, J. (2013) Uncovering the links between foraging and breeding regions in a highly mobile mammal. Journal of Applied Ecology, 50; 499-509.

describe the extent of 'forging trips' of grey seals for which we have telemetry data in the general area of the Irish Sea. Foraging trips are defined in terms of intervals between periods hauled out ashore. A haulout start is defined as the tag reading dry continuously for 10 minutes and the end is when it is continuously dry for 40 s. We define a trip to start when the interval after a haulout exceeds one hour and the seal is greater than 1 km from the departure haulout site. It ends when the seal next hauls out. Due to occasional large locations error and occasional paucity of recorded locations, there can be locations error in the interpolated start and end of a trip. Thus the start and end points are related to the nearest known (from terrestrial survey records and other telemetry data) haulout. The occasional problem of a seal triggering a haulout event at sea due to extended surface intervals is not currently included. Within each trip we record duration and maximum distance (maximum extent) from either the departure or arrival haulout sites.

Results

The telemetry data considered here comprise two sets of grey seal tagging in Wales:

- a total of 18 adults captured in Ramsey, Bardsey and Hilbre Island were fitted with Argos satellite tags (mean duration 13.9 days).
- a total of 17 pups in 2009-10 in Ramsey, Bardsey and off Anglesey were fitted with GPS phone tags (mean duration 150.2 days).

The tracks of these two deployments are shown in Figure 6a and 6b.

The results as requested in this question are presented in Table 7, grouped by age class (pup and adult). A total of 1722 trips were identified (pups, 982; adults 740).

Table 7. ***Statistics of trips, grouped by age class (pup and adult).***

pup ref	n	median (95% CI) duration (days)	median (95% CI) max extent (km)	mean max extent (km)	max max extent (km)
hg27-01-09	64	1.67 (0.17-8.60)	15.45 (1.56-88.91)	21.7	109
hg27-02-09	17	0.62 (0.38-7.52)	8.80 (3.20-210.38)	44.66	241.9
hg27-03-09	4	1.44 (0.42-3.26)	18.85 (9.04-31.15)	19.53	31.8
hg27-04-09	70	2.12 (0.11-6.21)	24.10 (1.10-99.35)	26.1	163.4
hg27-07-09	158	0.79 (0.17-3.61)	7.30 (1.20-55.70)	8.92	59.7
hg29-11-10	100	0.54 (0.12-11.73)	10.80 (1.00-105.08)	36.73	435.8
hg29-13-10	59	0.88 (0.25-4.08)	5.30 (1.43-26.99)	6.82	41.3
hg29-15-10	84	2.23 (0.12-7.63)	17.80 (1.20-63.63)	20.48	101.4
hg29-16-10	51	0.92 (0.33-7.79)	5.90 (1.35-55.87)	14.57	339.7
hg29-18-10	17	0.75 (0.12-24.15)	14.00 (1.16-152.50)	34.32	158.1
hg29-19-10	97	1.17 (0.21-3.57)	9.30 (2.14-25.94)	11.29	49
hg29-20-10	12	1.67 (0.47-5.83)	15.85 (3.77-31.22)	17.3	31.5
hg29-21-10	39	0.75 (0.08-8.49)	8.10 (1.28-103.11)	24.95	103.3
hg29-22-10	99	1.54 (0.25-5.07)	5.80 (1.44-79.70)	16.76	84.3
hg29-23-10	13	1.46 (0.22-6.10)	13.20 (2.78-35.16)	14.61	39.3
hg29-24-10	9	1.42 (0.60-2.07)	8.60 (4.06-12.66)	8.47	13.2
hg29-25-10	89	0.71 (0.12-8.67)	7.30 (1.10-88.10)	26.2	175.4
summary	982	0.92 (0.12-7.89)	8.5 (1.2-94.14)	19.47	435.8

adult ref	n	median (95% CI) duration (days)	median (95% CI) max extent (km)	mean max extent (km)	max max extent (km)
hg7-114M10-04	33	0.29 (0.04-8.15)	4.70 (1.10-85.80)	22.72	113
hg7-116F16-04	20	0.52 (0.23-8.71)	3.25 (1.15-89.87)	15.62	103.5
hg7-122F18-04	75	0.46 (0.12-3.62)	4.70 (1.20-44.76)	8.88	49
hg7-126F6-04	49	1.50 (0.14-3.61)	8.50 (1.22-58.92)	17.36	82.4
hg7-129F8-04	36	0.65 (0.08-7.30)	6.55 (1.00-120.42)	35.13	136.7
hg7-136F1-04	5	0.71 (0.43-0.96)	4.80 (1.75-9.14)	4.82	9.5
hg7-140M14-04	64	1.08 (0.15-4.73)	12.10 (1.06-58.44)	18.29	86.3
hg7-151M13-04	74	0.46 (0.21-5.16)	2.95 (1.00-67.08)	12.45	162
hg7-157F15-04	23	0.88 (0.19-4.96)	6.70 (1.16-40.99)	10.13	41.7
hg7-158M9-04	55	1.75 (0.17-6.25)	26.80 (1.20-113.13)	33.47	133.7
hg7-187M11-04	41	0.54 (0.17-7.96)	6.80 (1.30-82.10)	21.93	82.9
hg7-196M2-04	16	1.17 (0.38-3.97)	5.55 (2.24-22.51)	9.03	24.5
hg7-55F17-04	84	0.38 (0.21-4.08)	4.85 (1.20-158.26)	21.85	172.6
hg7-56F19-04	74	0.77 (0.24-3.14)	2.90 (1.08-55.71)	6.81	91.3
hg7-59M4-04	16	0.50 (0.06-1.42)	4.35 (1.34-41.25)	9.31	42.3
hg7-63F3-04	25	1.00 (0.11-4.73)	7.30 (1.18-75.68)	18.96	78.8
hg7-84M5-04	50	0.83 (0.29-3.30)	6.45 (1.15-64.83)	9.86	82.4
summary	740	0.75 (0.12-5.61)	5.2 (1.1 8-7.96)	16.94	172.6

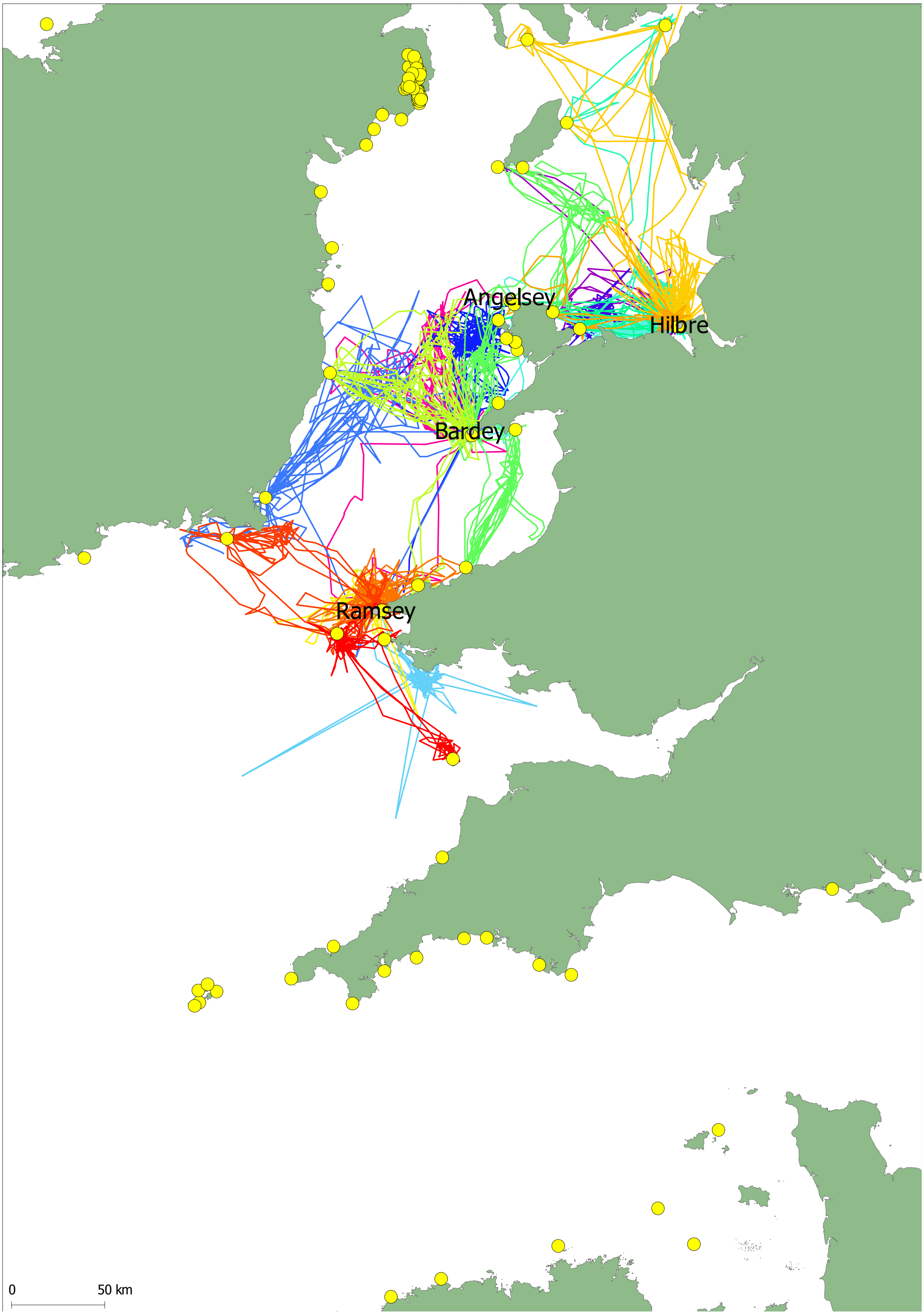

*Figure 6a. **Tracks of adult grey seals tagged in Wales, colour-coded by individual**. 'Known' haulout sites are indicated with a yellow circle. Capture locations are labelled.*

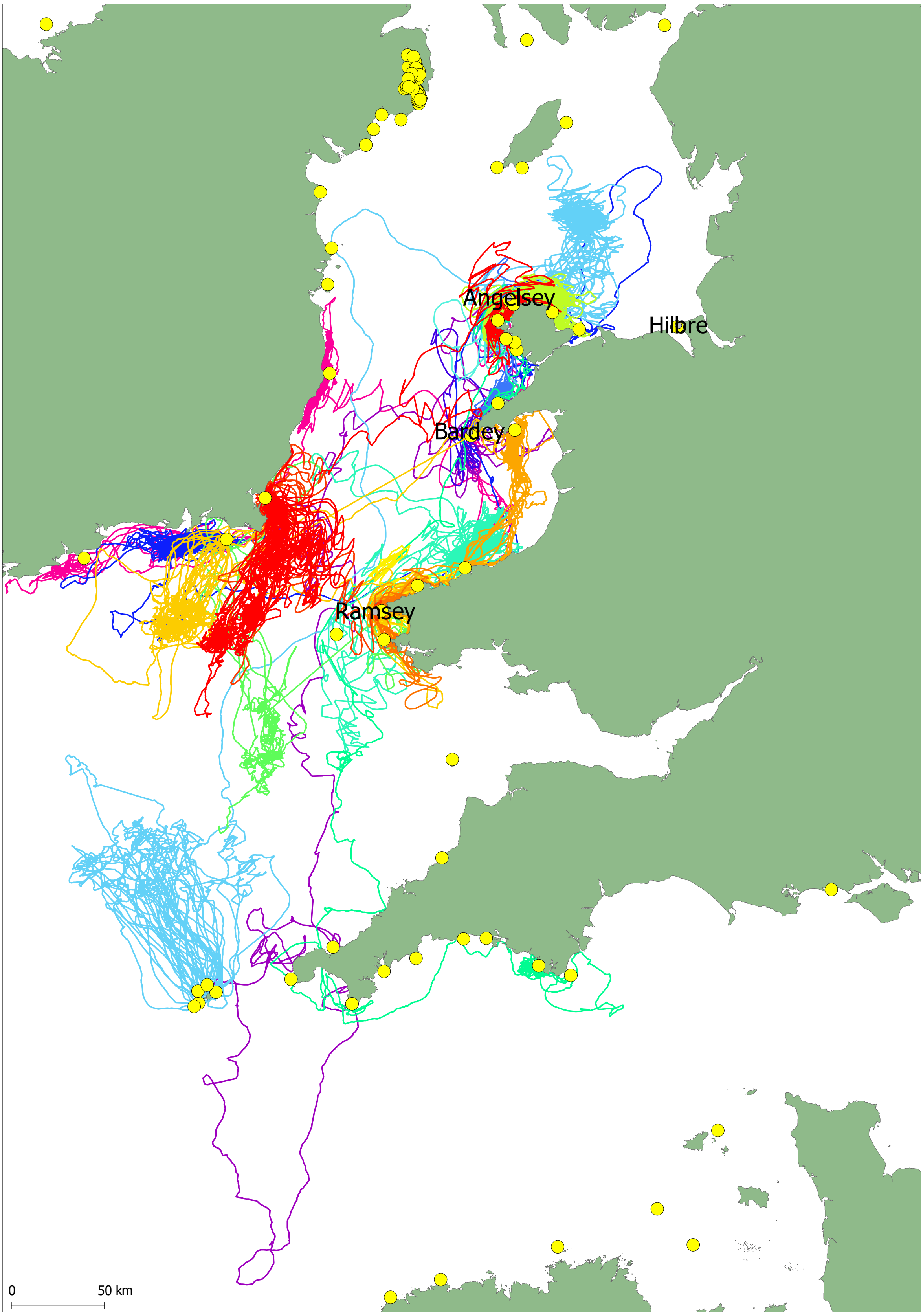

Figure 6b. ***Tracks of grey seal pups tagged in Wales, colour-coded by individual****. 'Known' haulout sites are indicated with a yellow circle. Capture locations are labelled.*

8. Are there any disease outbreaks which are likely to have a significant impact on English seal populations within the next 12 months and if so, what practical mitigation measures might be possible and appropriate?	Defra Q7

SCOS is unaware of any disease outbreaks likely to impact English seal populations. The mitigation response would be context specific.

PDV is known to be a recurring disease and there is a possibility of another outbreak in the next few years given the currently estimated inter-epidemic period.

Grey Seal Populations

9. What progress has been made in integrating grey seal population abundance models or selecting between these models using grey seal survey work undertaken in 2009?	Defra Sec Q1

This is addressed in response to Question 1.

The long term studies have provided updated survival and fecundity estimates for adult female grey seals and from the independent estimate of the number of grey seals in the population it is clear that the density dependent pup survival model best explains the regional trends in pup production (see SCOS-BP 14/02).

Harbour Seal Populations

10. Is the decline in harbour seals recorded in several local areas of the UK continuing or not and what is the position in other areas?	MS Q3; Defra Sec Q3;

The status of local harbour seal populations varies around the UK. Details of surveys carried out and the counts obtained are given above in answer to Question 1 and in SCOS-BP 14/03.

The decline in harbour seals in Scotland is continuing and details are given in SCOS-BP 14/03. Harbour seal surveys carried out in 2013 showed that the harbour seal decline continues in Orkney and the north and east coasts of Scotland, with the lowest counts recorded for each of these areas. The Moray Firth count also declined but from a fairly stable recent history, although recent finds of “corkscrewed” harbour seals in the Moray Firth are of concern. In contrast, the count for the surveyed section of north-west Scotland, from Cape Wrath to Ullapool, increased. At present, harbour seal numbers in Orkney and on the north and east coasts of Scotland still appear to be declining and are of concern. Harbour seal numbers in the Moray Firth require continue surveillance.

The population trends in the different survey/management regions around Scotland are shown in Figure 7. The latest survey results confirm that:

- The Orkney and North Coast harbour seal population has been falling at an average rate of approximately 11% p.a. since the decline here was detected in 2006.

- The Shetland harbour seal population declined by approximately 30% between 2000 and 2006. However, the Shetland survey in 2009 produced an identical count to that in 2006. Again, this suggests that the rapid declines may have ended but additional count data will be required to test this.
- The Western Isles harbour seal population has fluctuated without an obvious trend.
- In the annually surveyed area within the Moray Firth (Helmsdale to Findhorn), the mean count of adults from four breeding season surveys and the single moult count were both the lowest since 2010 (Figure 7). Given the variation in these counts over the years, this does not necessarily indicate a decline in this region.
- The severe decline in the Firth of Tay and Eden Estuary harbour seal SAC continued, with the 2013 moult count (50) being the lowest recorded to date, 43% lower than the 2012 count (88, Figure 8). This new count suggests that only 8% of the average population counted between 1990 and 2002 currently remain within this harbour seal SAC.
- No additional declines have been identified in other parts of the UK, for which new data is available (i.e. east coast of England, NW Scotland), where populations seem to be stable or increasing.

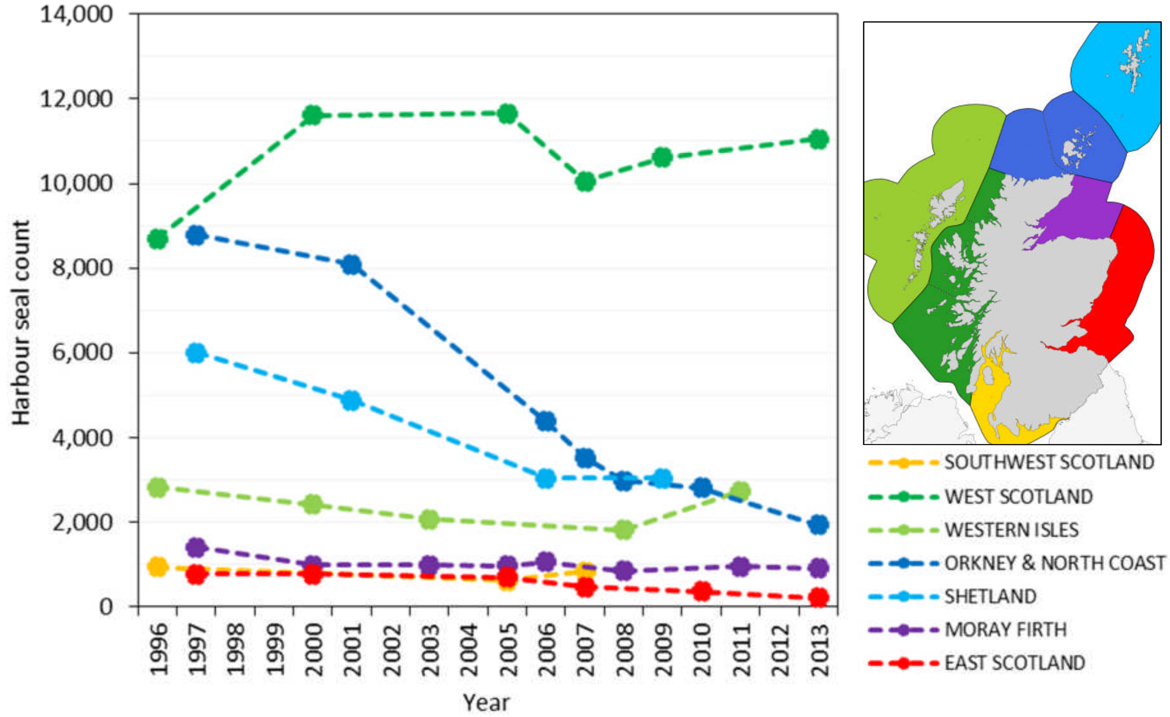

Figure 7. ***Counts of harbour seals in management areas in Scotland****. Data from the Sea Mammal Research Unit. Note that because these data points represent counts of harbour seals distributed over large areas, individual data points may not be from surveys from only one year. Points are only shown for years in which a significant part of the management area was surveyed.*

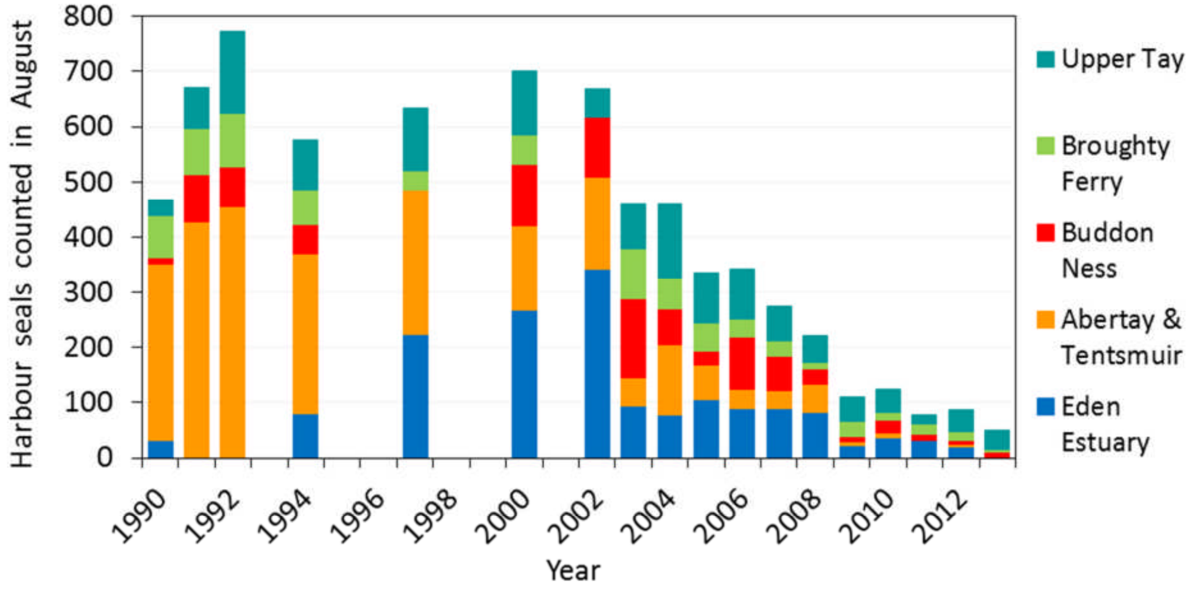

Figure 8. ***August counts of harbour seals in different areas of the Firth of Tay & Eden Estuary SAC, 1990-2013****. Data are from the Sea Mammal Research Unit.*

11. In light of the latest reports, should the Scottish Government consider additional conservation measures to protect vulnerable local common/harbour seal populations in any additional areas to those already covered by seal conservation areas or should it consider removing existing conservation measure in any areas?	MS Q4

The measures to protect vulnerable harbour (common) seal populations should remain in place.

The dramatic decline in the population of harbour seals in the Firth of Tay and Eden Estuary SAC is a clear cause for continued concern. In addition, a further decline was seen in Orkney.

Conservation orders are currently in place for the Outer Hebrides, Northern Isles and down the east coast as far as the border. Following the same precautionary principle as earlier (SCOS 2012), a conservation order was extended to the Outer Hebrides. The recent large increase in the Outer Hebrides is unexplained and in light of the uncertainty in the current status of the population SCOS recommends that the conservation order should remain in place.

12. What are the latest results from research investigating the causes of the recent decline in common seals and how has this improved understanding of the potential causes?	MS Q5; Defra Sec Q4;

The priority areas for further consideration include natural factors (competition with grey seals and the impact of toxins from harmful algae) and anthropogenic factors (interactions with vessels). A second workshop was held at SMRU to discuss the development of a research programme to investigate these specific factors.

A second workshop into the causes of the harbour seal decline, funded by Marine Scotland was held at SMRU in April 2014. The primary aim of the workshop was to "discuss the main candidate drivers responsible for the sharp decline in harbour seal numbers on the Scottish East Coast, Orkney and Shetland and develop an empirical and statistical research approach for investigating their role in future population trajectories." The main drivers of interest were competition for prey with grey seals (resulting in decreased condition and/or fecundity and/or increased mortality in harbour seals) and increased mortality from harmful algal toxin uptake. The workshop concluded that a comparative study of, for example, body condition, toxin exposure, diet, fecundity and survival in harbour seals should be carried out in regions with different population trajectories. This will be taken forward for funding in future.

13. In those areas where a decline in common/harbour seal numbers has been recorded in recent years, given a business as usual scenario, what is the projected future population growth/decline?	MS Q7

The population trajectories for areas showing a decline in abundance are generally continuing (except Shetland which is more uncertain as the two recent counts in 2006 and 2009 did not show a continuing decline). However, without knowing the underlying causes it is difficult to predict future trends. This highlights the importance of identifying the factors involved in the abundance decline.

A detailed analysis of the likely trends in the Tay and Eden SAC were presented at SCOS 2012 in SCOS-BP 12/04. This is the area with the most rapid and prolonged decline in Scotland, having experienced a 93% decline since 2000. Simple population models suggest that the continuation of current trends would result in the species effectively disappearing from this area within the next 20 years and while the cause of the decline is unknown it must be reducing adult survival.[9] However, this analysis is based on the assumption that the population vital rates (survival and fecundity) will not change. The reliance on this assumption means that these trends are associated with a great deal of uncertainty.

14. What potential mitigation measures might be useful to slow the decline or assist in the recovery?	MS Q6; Defra Sec Q5;

This is impossible to answer without knowing the cause or causes of the decline and recognising that this may be different in different areas.

15. And what are the key questions about seal populations that remain to be addressed to better inform practical seal management issues?	MS Q6; Defra Sec Q5;

Information on how vital rates vary between regions with different trajectories will be the key to understanding the drivers of population change. This will involve developing a time series of vital rate estimates which will take a number of years to generate but which will explicitly address the question what is causing the decline in abundance.

16. What progress has been made in improving monitoring methods and abundance estimates of the common seal population?	Defra Sec Q2

State-of-the art methods which are used worldwide and which are the most cost-effective are currently being used to estimate the abundance of harbour seals.

The number of seals hauled out during their annual moult in August, when they spend the largest proportion of their time on land, are photographed and counted.

Most regions are surveyed by a method using thermographic aerial photography although conventional photography is used to survey populations in the east coast estuaries. SMRU aims to survey the whole coastline across five consecutive years. The majority of the English and Scottish east coast populations are surveyed annually.

Although the estimated number of seals in a population based on these methods contains uncertainty, efforts are made to reduce the effect of these factors by standardising the time of year and weather conditions and always conducting surveys within two hours of low tide.

Management units (IAMMWG and ICES MUs[15]) and impact assessments

17. Do the seal MUs adequately define the 'populations' against which impacts should be assessed?	NRW Q8

Seal Management Units (MUs) were not set up to define populations but in response to the requirements of various legislative drivers, particularly the Marine (Scotland) Act 2010 and the Marine Strategy Framework Directive (MSFD). Impacts on individuals within one MU may be seen at the population level within another, depending on the species, location and the size of the MU of interest.

The seal MUs are a pragmatic approach to the policy requirement in response to the needs of management and assessment (such as determining the level of potential biological removal for a given MU, issuing licences and assessing population status) which need to be carried out at a regional level. For MSFD these units were to allow the regional assessment of population abundance and distribution in relation to the targets and indicators (see SCOS-BP 14/06). Given the movement of, particularly grey seals, between MUs, impacts on animals may have effects at the population level outside the particular MU with which the 'population' is associated. But the extent to which animals within a region can be assigned to a population is difficult. To the extent that seal distribution coincides with an MU then impact may be seen elsewhere but it is difficult to assess this in many cases. This is particularly so for breeding sites where grey seals may forage and be impacted by drivers well outside the region where they breed (for example high numbers of grey seals are now seen in the southern North Sea during the summer but they clearly breed elsewhere, see SCOS-BP 14/03). Animals may use multiple MUs during the course of a year and recent analysis by Russell et al (2013[14]) indicates that distribution is very dynamic.

[15] IAMMWG – Inter-agency marine mammal working group; ICES – International Council for the Exploration of the Seas; MU – Management Units

18. What is the degree of interchange and connectivity between MUs and how does this affect the biological validity of defining MU populations?	NRW Q9

For grey seals there are extensive movements between neighbouring MUs throughout the North Sea and within MUs and other regions (e.g. Ireland and France) in the west (see also answer to Question 6 and Question 7). More details on the relationship between foraging and breeding locations are given in Russell et al (2013[14]).

19. How should developments that border several MUs apportion their impacts on the 'populations' in these MUs? Can we apportion impacts identified within defined management units to specific SAC 'populations/assemblages'?	NRW Q10; NRW Q11

These two questions only differ in terms of spatial scale. SACs are within individual MUs so if we have sufficient information on (a) the proportion of the population that is being impacted, (b) the consequences of the impact and (c) some information on the connectivity between the impact site and the SAC or other MU this would be possible.

20. There is a philosophical difference between an impact / change that is detectable and that which is acceptable. What do SCOS think is an appropriate threshold for acceptable impact / change, e.g. mortality / auditory injury / displacement, in seal populations (within MUs) and should this be equitable to established guidelines in other taxa e.g. Favourable Conservation Status (1%), IWC bycatch (1.7%)?	NRW Q14

This is more of a conservation management issue rather than a science question. See discussion under Question 50 in relation to the MSFD seal targets and (SCOS-BP 14/06)

Seal legislation

21. Does the committee consider that there is a significant scientific requirement to change the current close seasons for each native seal species?	Defra Sec Q6

SCOS does not see a need to change the definition of the close season for grey seals. At present there is a conservation order in force along the entire east coast of England and Scotland. This order protects almost the entire English harbour seal population. While this is in force the close season is effectively extended to the whole year.

Seal Diet

22. What are the key findings arising from the results of the current seal diets study for grey and common seals? What is the latest estimate of consumption of commercially important fish by seals in English waters? Does it differ regionally with particular emphasis on SW Britain?	MS Q8; Defra Q4; NRW Q15

The current seal diet study is now complete but there is no recent research on the diet of seals in SW Britain.

Harbour and grey seal diet around Scotland and the east coast of England was studied regionally and seasonally over a 12 month period in 2010-11 to provide estimates of diet composition and prey consumption from samples of hard prey remains (fish otoliths and cephalopod beaks) recovered from scats collected at haul-out sites. The analytical methodology was based on that developed previously for similar studies of grey seal diet in 1985 and 2002[16].

Harbour seals

New experiments were conducted with captive harbour seals to estimate coefficients to account for partial and complete digestion of otoliths and beaks. Some differences were found between these new results and those previously obtained for grey seals but overall the results were broadly consistent between the two species of seal. The new results were used in analysis of harbour seal diet.

Diet composition for harbour seals was estimated by management region around Scotland and The Wash on a seasonal basis. Although data are not available for all seasons in all regions, overall a comprehensive coverage was achieved throughout. A wide range of prey types was consumed: sandeel, gadoids, flatfish, scorpion fish, sandy benthic fish, pelagic fish and cephalopods. Diet composition varied seasonally and regionally throughout Scotland and The Wash. Prey diversity and diet quality were also explored and showed some regional and seasonal variation.

Sex-specific differences in harbour seal diet were investigated in the Moray Firth, two west coast regions and The Wash. Observed differences between the sexes in prey diversity and diet quality were generally small. There were some sex-specific differences in diet composition on the west coast and The Wash but not in the Moray Firth.

Estimates of annual consumption by harbour seals will be available for the west coast (ICES Division VIa) and North Sea, including Shetland and Orkney (ICES Area IV).

Grey seals

Diet composition was estimated seasonally for grey seals in the following regions: Shetland, Orkney and northern North Sea, Central North Sea (including northeast England), Outer Hebrides and Inner Hebrides. As found previously in 1985 and 2002, the major prey species in the diet were sandeels and large gadoids; however, some marked differences were seen in 2010/11 compared to 2002 (and 1985). In 2010/11, the proportion of gadoids in the diet increased in Orkney and Shetland but decreased in the Inner and Outer Hebrides and the central North Sea. Conversely, in 2010/11, the

[16] Hammond, P.S., Grellier, K., (2006), Grey seal diet composition and prey consumption in the North Sea. Final report to Department for Environment, Food and Rural Affairs on project MF0319. 54pp. and Hammond, P.S. & Harris, R.N. (2006). Grey seal diet composition and prey consumption off western Scotland and Shetland. Final report to Scottish Executive Environment and Rural Affairs Department and Scottish Natural Heritage

proportion of sandeels in the diet decreased in Orkney and Shetland but increased in the Outer Hebrides and central North Sea.

Estimates of annual consumption by grey seals of major prey species will be available for the west coast (ICES Division VIa) and North Sea including Shetland and Orkney (ICES Area IV). Estimates from 1985 and 2002 will be presented for comparison.

Comparison of harbour and grey seal diet

Comparison of diet composition, prey diversity and diet quality between harbour and grey seals has been initiated. Some seasonal and regional differences between species are apparent but no overall consistent pattern emerges to link these differences with observed regional changes in abundance in the two species.

Consumption of fish in English waters

The seal diet project focussed around Scotland but there are data for harbour and grey seals from haul-out sites along the east coast of England from which seal diet composition and fish consumption can be estimated.

Based on the methods described for the analysis of harbour and grey seal diet in Scottish waters, estimates of diet composition from data collected in 2010-2012 will be available for two areas of the North Sea:

1. Southern North Sea – grey and harbour seal

2. Central North Sea – grey seals. This area includes southeast Scotland as well as northeast England because the seals in this area mix across the England-Scotland border.

Estimates of annual consumption will be available for these areas for the following commercially caught fish species: cod, whiting, plaice, lemon sole, Dove sole, herring, sprat and sandeel. Estimates from 1985 and 2002 will be presented for comparison. SW Britain was not included in this study.

Seals and salmon netting stations

23. What is the current state of knowledge of interactions between seals and salmon netting stations and possible mitigation measures and what are the priority areas for research in terms of practical non-lethal options? In the 2013 advice, you refer to net modifications mode in 2012 which had a positive result in reducing seal impacts. Could you explain what those modifications were?	MS Q9; Defra Sec Q7 and Sec Q8

SMRU's work on the interaction between seals and salmon netting stations is continuing. Priority areas are improved net design, improved acoustic deterrent devices (ADDs) and a study of the long term effectiveness and seal habituation to ADDs. Although catches were again higher when ADDs were in use, results obtained in 2013 were less marked than previously. Modified nets, including a narrower entrance to the fish court and changes to the netting to reduce the chances of seals chasing fish into the corners of the net, are being tested. The results are difficult to interpret, as the modified net yielded a higher proportion of damaged fish than the traditional net, but the actual landings per unit effort were significantly higher at the modified net. Future work will focus on further modifications as well as why some seals may be less responsive to ADDs than others.

SMRU continues to work with commercial salmon netting stations in the Moray Firth. During 2013 work was focused in two areas, the Tarbat Ness Peninsula in Easter Ross (at Portmahomack) and around Gardenstown (mainly at Crovie). Research is directed towards minimising seal interactions with netting stations. Two approaches are being taken. ADD use is being trialled at two sites, while net modifications are being tested at Balintore (in 2012) and data analysed in 2013, in addition net modifications were trialled near Gardenstown in 2013 and 2014.

Improvements to the housing of one acoustic deterrent device (ADD) system have been made. A second model of ADD – powered directly from the mains – is being tested and a modified net is being compared with a traditional net as a possible means of limiting seal damage.

At Portmahomack where an ADD has been in use for several years, improvements to the battery housing and cabling were made during 2013. No problems were encountered with this deployment method in 2013. However, the inability of the system to be completely submerged for long periods and the durability of the housing mean that, although suitable for testing purposes, this method is probably not suited to long-term commercial use and further refinement will likely be needed by the manufacturer or the fishery.

The marked reduction in damage attributed to the use of the ADD in previous years was less noticeable in 2013. Although overall catches were still higher when the ADD was in use, around 17% of landed fish were damaged whether the device was on or off. However, on and off periods were not randomly assigned but were due to operational issues. The apparent increase in damage rates when the ADD was operational during 2013 compared with previous years will be investigated in more detail during the 2014 field season.

An Airmar ADD was tested during 2013 at Crovie using randomly assigned on and off days. Fish catches were low and seal sightings were also very low during the 2013 season at this net, so no conclusions can be drawn so far; it is planned to continue this work for five seasons in total. Underwater video footage is also being collected at two net fishing sites near Crovie.

Modified nets were tested at Balintore during 2012. These follow a design implemented by a local salmon fishing company – including a narrower entrance to the fish court, and changes to the netting to reduce the chances of seals chasing fish into the corners of the net. The modified net yielded a higher proportion of damaged fish than the traditional net, but the actual undamaged landings per unit effort were significantly higher at the modified net. Although underwater video was only available for a short period of the trial, video recordings suggested that seals remove more fish whole from the traditional net, but that fish are also slower to enter the fish court of the modified net, increasing the risk of being depredated in the outer sections of net.

Future research should focus on further net modifications, on continued trials of different acoustic deterrents systems rigged specifically for use at salmon netting stations, on understanding if or why some seals may be less responsive to acoustic deterrents, and monitoring cetacean reactions to the use of such devices at netting stations.

Modified nets included four changes to the traditional Scottish single bag-net:

- Replacement of the rope framed entrance to the inner chamber (fish court) with 8mm stainless steel bars welded into 6 rectangular shapes each measuring 43cms by 15cms to prevent seal entry.
- Heavier net material in the fish court to prevent seals breaking the net and to increase the difficulty for seals to take fish through the net meshes (2mm twisted polyethylene ('Courlene') increased to 4mm braid).
- Traditional nets typically have a larger mesh size for the floor, this was reduced in the modified net to the industry minimum (90mm);
- Tight corners within the fish court were closed off to reduce the chance of fish being cornered by seals.

Seals and fish farms

24. What is the current state of knowledge of interactions between seals and fin fish farms and possible mitigation measures and what are the priority areas for research in terms of practical non-lethal options?	MS Q10; Defra Sec Q9

Studies to further understand the issue of seal depredation at fish farms are ongoing. Priorities are to better understand how seals remove fish from salmon pens; how the various husbandry practices such as net tensioning and mortality removal may hinder such actions; how well each of the available ADDs work and how they each affect cetaceans, in the long term.

SMRU continues to work with industry both to better understand the issue of seal depredation at fish farm sites, and to test new deterrent systems, but little has been completed so far since last year's SCOS report.

An ADD that is based on a startle response (using short rapid onset acoustic signals) and that was developed with Marine Scotland funding several years ago[17] is currently being commercialised and field trials of a prototype were conducted in 2010-2011. Results were encouraging in that ongoing seal depredation at one site was reduced to very low levels for a year until harvest, while at two other sites where seal depredation had become an issue, further depredation was eliminated during two short term trials. A report of this work is now available[18]

Work described in last years' SCOS report and funded by Marine Scotland has now been published[19]. Ongoing work funded by SARF (Scottish Aquaculture Research Forum, Report number SARF071) aims to use video cameras to understand how seals attack salmon pens, to use angular momentum data loggers to quantify deformations in the netting of cages in different tidal regimes, and to examine the capabilities of captive seals to remove dead fish from replica salmon pens. Further work on localised electric fields to deter seals from nets is also being planned.

Occurrences of seals in fresh water in relation to seasonal salmon runs

25. What is the regularity of such an occurrence?	Defra Sec Q10

SCOS is not aware of any information on the frequency or timing of these occurrences in English rivers.

[17] Götz, T., Janik, V.M., 2011. Repeated elicitation of the acoustic startle reflex leads to sensitisation in subsequent avoidance behaviour and induces fear conditioning. BMC Neuroscience 12.
[18] Janik, V and Gotz, T. 2013. Acoustic deterrence using startle sounds: long term effectiveness and effects on odontocetes. Report to Marine Scotland, 24pp (http://www.scotland.gov.uk/Publications/2013/11/9261/0).
[19] Northridge, S., Coram, A., Gordon, J., 2013. Investigations on seal depredation at Scottish fish farms. Edinburgh, Scottish Government. Available from http://www.smru.st-andrews.ac.uk/pageset.aspx?psr=152

26. Where are the common freshwater locations of such occurrences? What is the current state of knowledge on the occurrence of grey seals in freshwater in SW Britain? Where in the UK is this also known to occur and is there any information on seasonal occurrence of such behaviour?	Defra Sec Q11; NRW Q21

Seals are regularly seen in freshwater in the English East Coast Rivers such as the Tyne, Humber, Great Ouse and Thames and in rivers in Wales.

27. What are effective deterrents in such freshwater locations? Management – We would be especially interested in receiving the results of research into deterrents.	Defra Sec Q12

ADDs are effective seal deterrents that can be used in rivers where site characteristics are favourable. However, effectiveness in experimental trials does not always result in effectiveness in 'real world' deployments. Previous research has shown that ADDs can effectively reduce seal presence and salmon predation in rivers if properly deployed and controlled (Harris et al, 2014[20]).

28. What damage to salmon stocks is there as a result of seals in freshwater? What information if any is there on predation levels of salmon by grey seals in SW Britain and Welsh waters?	Defra Sec Q13; NRW Q22

SMRU does not collect data from fisheries managers.

29. What information, if any, do you have on numbers of complaints of seal damage in England?	Defra Sec Q14

SMRU does not collect complaints from fishermen. Such complaints would normally be made to District Salmon Fisheries Boards (DSFBs) in Scotland and the Environment Agency in England in relation to salmon or to the relevant fishery management agencies in each of the national regions.

SMRU manages the UK's protected species bycatch monitoring scheme and as such has worked with hundreds of UK fishermen over the past decade, and is aware that there are very strong feelings in the static gear sector about seal depredation. An examination of unpublished data from the SMRU monitoring scheme suggests that at least 6% of observed static net hauls in the UK are affected by seal damage to some degree, with higher rates in some fisheries, with recorded losses of at least 20% of all fish decked.

[20] Harris, R.N., Harris, C.M., Duck, C.D. and Boyd, I.L. (2014). The effectiveness of a seal scarer at a wild salmon net fishery. ICES Journal of Marine Science, DOI: 10.1093/icesjms/fst216

30. What information, if any, do you have on seals being killed in England to prevent damage to fisheries during the 'open seasons'?	Defra Sec Q15

The Marine Management Organisation (MMO) gathers seal shooting intelligence (from reports made to them) as a requirement for the PAW (Partnership For Action Against Wildlife Crime) tasking and coordination group. The MMO pass on any intelligence to the Police wildlife crime unit (although note that illegal seal shooting has recently been removed as an intelligence requirement from the National Wildlife Crime Unit's Strategic Assessment).

31. What information, if any, do you have on seals being killed under the fisherman's defence, provided by s.9(1)(c) of the Act?	Defra Sec Q16

SCOS is not aware of any information on numbers of seals being killed in England under the 'fisherman's defence'. There are no reporting requirements in England and therefore no reliable records

Seals and marine renewables

32. What is the current state of knowledge of interactions actual or potential, between seals and wet renewable (tidal turbine) devices and possible mitigation measures?	MS Q11; NRW Q16

A study funded by NERC entitled "How marine renewable device operations influence fine scale habitat use and behaviour of marine vertebrates (RESPONSE)" and another funded by Marine Scotland entitled "Trialling methods for tracking the fine scale underwater movements of marine mammals in areas of marine renewable energy" are both underway and will report their findings over the next 18 months.

The most up to date information on the effects of offshore marine renewable energy generation can also be found in a report for the Scottish Government:- Thompson, D., Hall, A.J., Lonergan, M., McConnell, B. & Northridge, S. (2013)[21], available at http://www.smru.st-and.ac.uk/pageset.aspx?psr=152.

[21] Thompson, D., Hall, A.J., Lonergan, M., McConnell, B. & Northridge, S. (2013) Current status of knowledge of effects of offshore renewable energy generation devices on marine mammals and research requirements. Edinburgh: Scottish Government

33. What potential interactions can we rule out at this time in respect of specific types of renewable device, particular stages of their development (i.e. construction and operation) and seals?	MS Q12

Current evidence suggests there is no large scale and long term displacement of animals from operational wind farms.

Using telemetry tags harbour and grey seals were observed within an operational windfarm with no apparent differences to behaviour in control areas[22]. Furthermore, of harbour seals tagged in the Thames (n=10) and The Wash (n=22) in 2012, eight and seven respectively, entered operational windfarm suggesting animals are not completely displaced from them. Our findings do not preclude the possibility of short term displacement during vessel activity or even complete short range displacement by some individuals from operating turbines. However, we have found that some individual seals spend prolonged period at the foundations of the turbines themselves, probably because of foraging opportunities produced through an artificial reef effect[13].

34. What additional work might most effectively improve assessment of possible impacts of marine renewables on seal populations at regional and national level?	MS Q13

Understanding fundamental drivers of population change (particularly those behind the current trends), the levels of displacement and effects on vital rates are critical to determining impacts at the population level. Thus understanding how specific exposure – response relationships may impact demography is of high priority.

35. What evidence exists about how seals behave around tidal turbine devices, including diving behaviour, and about what might be an appropriate avoidance rate to be applied in collision risk modelling? What is the current thought on suitable mitigation measures for reducing collision risk with turbines in strong tidal conditions?	MS Q14; NRW Q17

It is not possible to estimate avoidance rates that are central to the collision risk models available for these assessments. Operational mitigation measures that have the potential to reduce the risk of collisions include the use of ADDs to deter seals from approaching turbines. However, responses can be inconsistent and may affect non-target species.

Behaviour around operating tidal devices.
Currently there is only one study carried out in the vicinity of an operating turbine. Lonergan et al (in prep)[23] showed that an operating turbine in Strangford Lough Narrows made little difference to the rate at which seals transited along the Narrows past the turbine. However, the telemetry data were not of sufficient resolution to determine fine scale activity close to the turbine.

[22] McConnell, B., Lonergan, M., Dietz, R. (2012). Interactions between seals and offshore wind farms. The Crown Estates.

[23] Lonergan, M., C. Sparling, and B. McConnell. (in prep). Behaviour of harbour seals (*Phoca vitulina*) around an operational tidal turbine

In 2014 the SMRU was contracted by Scottish Government to develop a technical solution to detect and track marine mammals in the vicinity of an operational turbine. This study will be carried out wherever the first Scottish turbine is established (likely to be in the Pentland Firth).

A threefold approach will be taken: Active Sonar, Passive Acoustic Monitoring (it is proposed that PAM will be able to track seals fitted with acoustic pingers) and opportunistic Video Surveillance to detect actual collision events for a sub set of the deployment. This proof-of-concept project will report in mid-2015. It is anticipated that data capable of usefully informing collision models will be gathered the following year.

Mitigation

Perhaps the most effective mitigation for reducing collision risk would be to consider this risk at an early turbine design stage and include engineering mitigation measures through early design modifications (e.g. rotor speed reductions). Work is currently being carried out at SMRU to understand the effects of rotor impacts on seals and the influence of rotor speed on the likelihood of injury. This is due for reporting in December 2014.

In terms of operational mitigation, the only mitigation method that has been applied to tidal turbines so far is the shutdown protocol at Strangford Lough; this requires observers to monitor the outputs of a series of active sonar systems on the turbine and effect an automated shutdown if a target thought to be a marine mammal approaches within a pre-defined mitigation zone. However, this is clearly effort intensive and financially expensive; automated sonar detection systems are currently being developed and may prove an effective alternative in the future.

Alternative operational mitigation measures that have the potential to reduce the risk of collisions include the use of ADDs to deter seals from approaching turbines. However, given that behavioural responses by animals are likely to be highly context specific and will depend on factors such as age class, motivation of the animal to remain in the area, and prior exposure history, it is perhaps not surprising that reports of the effectiveness of ADDs is mixed. The use of ADDs was summarised for SCOS 2013.

36. What evidence exists about common/harbour seal range that might help define possible areas of concern for specific marine renewable developments?	MS Q15

Telemetry data (including high resolution data) are available to assess harbour seal movement and behaviour patterns within high tidal energy areas in several locations around Scotland.

Telemetry data from seals caught at sites close to areas of high tidal energy are included in the harbour seal usage maps that show the density of seal activity at sea at the resolution of a 5km grid (http://www.scotland.gov.uk/Topics/marine/science/MSInteractive/Themes/usage). There is a limit to where marine renewable energy developments will occur. In addition, the number of animals using a given region (influenced by prey distribution and population size) will be of particular relevance, especially in areas where population abundance is changing. Any ‘areas of concern’ would need to include an assessment of the cumulative effects of any additional factors operating in these areas.

37. What evidence is available that construction noise from marine developments e.g. from piling, deters seals from ensonified areas and are potential noise 'barriers' likely to have adverse impacts on grey seal populations	NRW Q12

Recent telemetry data on harbour seals in The Wash (n=24) shows that they were not excluded from the vicinity of the windfarm during the construction phase as a whole. This does not preclude the potential for exclusion during individual piling events.

Our findings that any large scale displacement of animals away from windfarms during piling is short term is supported by a haulout study on grey and harbour seals[24] showing that impacts on the number of animals hauled out were limited to piling events.

38. Can the resolution of current seal density maps be reduced (to 1 x 1 km) to take account of smaller development sites, which can be used in encounter risk models for specific marine renewable developments?	MS Q16

The resolution could be reduced but the extent to which it would reveal finer scale behaviour depends very much on the resolution of the telemetry data.

Seal usage maps can be run at any chosen resolution so 1x1km grid squares are possible. The main consideration would be whether finer-scale details could be extracted from the telemetry data through increased resolution. This would depend on (1) the amount of telemetry data in the study area; and (2) the fine-scale movements of animals in each grid square. Therefore, study areas with many telemetry data points with fine-scale movement (such as foraging areas) would be good candidates for this analysis.

Usage will appear more patchy when defined at a higher resolution: telemetry tracks are interpolated and regularised to 2-hourly intervals and seals can travel up to 15km in 2 hours when swimming in a straight line at $2ms^{-1}$. Therefore, a seal could travel up to 15 grid squares in the time between two consecutive telemetry locations. Although the usage is kernel smoothed, it will not appear continuous.

Another consideration is the processing time of the maps: 200,000 grid squares at $5km^2$ resolution for one species takes 5 days to process. Increasing the resolution to 1km would increase the number of grid squares to 5 million. Therefore, a full UK analysis would be unfeasible, so the analysis would be restricted to smaller areas of interest.

Seal Licensing and PBRs

39. What, if any, changes are suggested in the Permitted/Potential Biological Removals (PBRs) for use in relation to the seal licence system?	MS Q17

The provisional Regional PBR values for Scottish seals for 2015 are given in SCOS-BP 14/05.

[24] Edren, SMC., Andersen, SM., Teilmann, J., Carstensen, J., Harders, PB, Dietz, R. and Miller, LA. (2010). The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior. Marine Mammal Science, 26; 614-634.

40. Is the PBR the best method for dealing with potential collision risk involving marine renewable turbines (recognising that collisions may not always be lethal) or is there another more appropriate framework that might be applied in such circumstances?	MS Q18

PBR is an appropriate method for assessing the impacts marine renewable developments on seals if we have an estimate of the likelihood of seals being killed during such interactions.

The essential question is not whether PBR is a better or a more appropriate management procedure than any of the alternative yield based management procedures; it is how can we assess the likelihood of an interaction causing the death of an animal?

The potential problems with PBR are also likely to affect any other yield based management method and as stated above, the effects are likely to be small. In comparison, the effects of an unaccounted source of mortality could be relatively large, depending on the scale of that mortality. It seems therefore that the use of PBR is likely to be at least as effective as any other simple management model and follows the conservative management approach used in the US. Improved management of the interactions of marine renewable devices and marine mammals will depend on improved estimates of collision rates and the associated mortality rates.

Shooting

41. How effective are the current firearm and ammunition minima stipulated in the act in relation to the termination of a seal?	Defra Sec Q17

Results of the tests carried out into the effectiveness of different firearms for killing grey seals are still to be fully analysed. Harbour seals were not tested.

Unusual Seal Mortalities

42. What is the latest understanding of the causes of the recent unusual seal mortalities and their potential impact on wider seal populations? What are the occurrences of strandings that indicate these injuries occur in the West England and Wales management unit (MU)?	MS Q19; Defra Sec Q21; NRW Q19

Research into the causes of the unusual seal mortalities and their potential impact on the wider seal population is continuing.

In 2010 SCOS expressed its concern over the emergence of a new source of anthropogenic mortalities (so called “corkscrew” seals) primarily of pregnant female harbour seals close to the Tay and Eden SAC. SCOS consider that without urgent mitigation the population will continue to decline. SCOS strongly recommended that this cause of mortality be urgently investigated and if identified should be removed or effective mitigation measures be put in place as soon as possible. A preliminary report of the investigation into this mortality event was presented in SCOS-BP 11/07.

Seals with characteristic corkscrew wounds have continued to wash ashore around Scotland with 11 cases so far in 2014 (6 Harbour seal and 5 Grey seal, Table 8). Since 2010 these events have been mainly concentrated in Scotland. There were no recorded corkscrew seals in England in 2011 or 2012 but three were found close to Blakeney in March 2013.

Table 8. ***Numbers of grey and harbour seal carcasses with characteristic corkscrew wounds recorded in the UK.***

Year	Harbour Seal	Grey Seal	Total	Comments
1985	2	0	2	
2007	0	1	1	
2008	2	0	2	
2009	4	1	5	
2010	39	28	67	13 Hg and 24 Pv from England. 4 Hg from Northern Ireland.
2011	10	16	26	
2012	7	17	24	
2013	9	16	25	11 Hg from England. 2 Pv from Northern Ireland.
2014	8	5	13	

There are unconfirmed reports of corkscrew seals in Pembrokeshire and North Devon. Penrose (2012) reports[25] three clear examples of corkscrew seals in late 2012 in Pembrokeshire and photographs were obtained of a probable example from Pembrokeshire in October 2011. Two seals with spiral lacerations and one headless seal were reported from North Devon in November 2013. Given the relatively high number of cases compared to the low level of reporting effort this would appear to be a potentially important issue in the West England and Wales Management Unit.

The latest understanding is that these wounds are consistent with interactions between seals and ducted propellers and tests using ducted propellers and model seals in a test tank produced similar wounds whilst non-ducted propellers did not. A full report on the findings of these tests can be found at http://www.smru.st-and.ac.uk/pageset.aspx?psr=152. A definitive observed encounter between a seal and a vessel has not yet been recorded but further research funded by Marine Scotland is designed to track the fine scale, real time movements of tagged seals in areas where encounters are likely to occur and during the development of a port where increased vessel traffic is anticipated.

43. What is the latest position on possible mitigation measures?	MS Q20; NRW Q20

Use of ADDs to exclude seals from specific areas during times of particular shipping operations may provide a potential mitigation measure, especially in areas where clusters of cases have been reported.

[25] Penrose, RS. (2013). Marine Mammal and Marine Turtle Strandings (Welsh Coast). Annual Report, 2012. www.strandings.com.

Results of ADD avoidance studies under the Marine Scotland funded Research Programme MMSS/001/11 suggest long range avoidance of particular signals. An analysis of those results, including an assessment of their potential as mitigation measures for a range of anthropogenic problems was presented to Marine Scotland in 2014. Scale model trials described above suggest that propeller speed significantly affects damage patterns on scale models. Modifications to shipping activity and operational procedures in coastal waters close to seal concentrations may be effective in reducing interactions. To design and implement such measure requires a detailed understanding of the circumstances under which these incidents occur.

To further develop mitigation measures we will need to understand why seals approach propellers and under which operational modes. This will require co-ordinated observations of vessel activity and seal swimming patterns as well as vessel based observations. An intensive telemetry and visual observation programme is planned to coincide with the increase in shipping activity during the development and early operation of port facilities at Ardersier in the Moray Firth. These real time observations should provide detailed insight into the behaviour of seals around candidate vessels and dramatically increase the chances of directly observing an interaction. If interactions occur the project plan includes capacity for trials of acoustic and operational mitigation measures.

An industry and regulator workshop to discuss and develop possible mitigation measures is planned for autumn 2014.

44. What potential mechanisms can be ruled out as a result of trials to date?	MS Q21

Recent results have shown the ability of ducted propellers to cause spiral lacerations in scale model trials. Under the same test conditions, open propellers (without a duct) and Voith-Schneider propellers did not produce these damage patterns.

This lends support to the suggestion that only vessels fitted with ducted propulsion systems are involved in the interactions. Preliminary trials with a straight bladed ducted propeller produced severe damage but not the characteristic spiral lesions. This may indicate that only specific blade shapes cause the corkscrew injuries. This will be investigated under on-going work at the VOITH facility and will be reported to SCOS in 2015. However, other propeller systems are clearly capable of inflicting other potentially serious or fatal injuries

Seal sizes (axial girth and length) were significant factors in determining which trials produced the characteristic lesions. This may help to explain the absence of large adult grey seals in the corkscrew seal record. Trials involving larger models did not demonstrate these lesions however damage to the front of the models may suggest that these mechanisms may result in cases of headless seals.

Predation

45. Are you aware of any grey seal predation on common seals in UK waters?	Defra Sec Q22

There are incidental observations and anecdotal reports of grey seal predation on harbour seal pups in Orkney in the late 1990s. Three harbour seal pups with bite wounds consistent with adult male grey seal predation were reported in the Moray Firth in 2011. Two anecdotal reports of grey

seals feeding on recently dead harbour seals at Blakeney in 2010 may represent scavenging on corkscrew injured seals.

There have been recent reports from Helgoland in Germany that a grey seal was observed interacting aggressively with a young harbour seal (biting and spinning it in the water) and a carcasses was found the following day with sever traumatic lesions consistent with the interactions observed the previous day[26]. Further observations of the same individual preying on juvenile harbour seals were subsequently made. In addition, a recent note[27] described evidence of grey seal predation and scavenging on harbour porpoise (*Phocoena phocoena*) which has also been reported in the UK.

Population Redistribution

46. Is there any evidence for the redistribution of grey or common seals in Scotland and if so, what are the likely causes of such changes?	MS Q22

There is no evidence of redistribution of harbour seals in Scotland.

Changes in distribution could occur either during the breeding or non-breeding (foraging) season. There may be local, fine-scale use of sites.

Harbour seals

Population declines in Orkney, Shetland and the Tay-Eden SAC have not been matched by population growth in neighbouring regions. The only increasing populations in Europe are in the Southern North Sea and there is no evidence of movements between these populations and the Scottish populations. However, there is little information on juvenile harbour seal movements so we cannot reliably state that recruitment patterns mirror the apparently sedentary patterns in adult harbour seals.

Grey seals

Recent survey results from the summer (SCOS-BP 14/03) show a large reduction in numbers of grey seals recorded in the Outer Hebrides, particularly at the Monach Isles. As these results are based on single surveys at five year intervals it is not known if this represents a transient effect, survey artefact or an actual decline in the local summer foraging population. Surveys planned for August 2014 will include the Monach Isles and should help clarify this issue.

The main apparent re-distribution of foraging grey seals in the UK has been the large scale increase in numbers of grey seals hauling out in the central and southern North Sea during the summer. The summer counts in eastern England have increased at an average rate of 20.8% p.a. since 2000 (Figure 9). Over the same time period the pup production at colonies south of the Farne Islands have increased at an average rate of 12% p.a. This dramatic increase in summer counts most likely indicates a seasonal movement of seals into the southern North Sea, presumably from breeding populations further north in the North Sea.

[26] Van Neer, A, Jensen LF, Bladel R and Siebert U. (2014). If you can't beat them, eat them – Behavioural observations of grey seal (*Halichoerus grypus*) and harbour seal (*Phoca vitulina*) interactions on the island of Helgoland, Germany. Poster presentation European Cetacean Society Annual Conference, Liege, Belgium

[27] Bouveroux, T, Kiszka, JT, Heithaus, MR, Jauniaux, T and Pezeril, S. (2014). Direct evidence for gray seal (*Halichoerus grypus*) predation and scavenging on harbor porpoises (*Phocoena phocoena*). Marine Mammal Science DOI: 10.1111/mms.12111

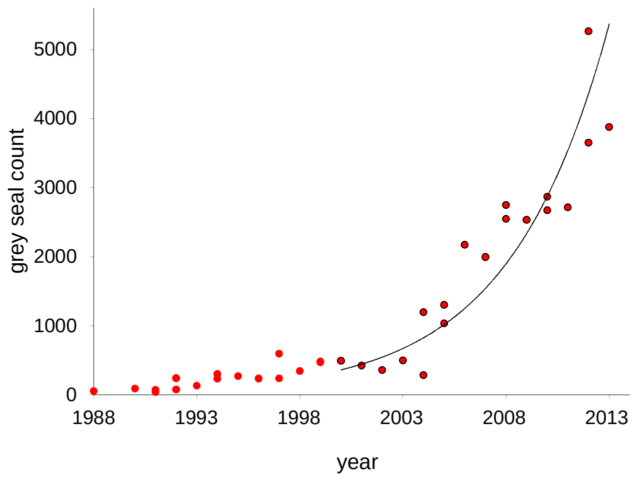

Figure 9. **Counts of grey seals in the southern North Sea (Lincolnshire to Kent) during August**.

Designated Seal Haul-out Sites

47. In light of 194 seal haul-out sites around Scotland being designated to protect seals from harassment, how frequently does the committee consider it would be useful to review these sites to ensure their continued relevance for the seals and/or to add new or remove redundant sites?	MS Q23

SCOS would suggest reviewing all previously designated sites as well as potential new sites every time a new set of August counts, covering the whole of Scotland, becomes available. A round-Scotland survey is usually completed every five years.

In addition, it would be desirable to have the option of designating individual sites at any time between general reviews (a good example is the recent increase in grey seal numbers at the Ythan Estuary). This would facilitate protecting a non-designated site in special cases where there is sufficient evidence that either (a) the number of seals using the site has increased rapidly, making it significantly more important than it was understood to be when last reviewed or (b) seals hauled-out at the site are (at risk of) being harassed."

Bycatch

48. What are the best estimates for the level of seal mortality from bycatch in Welsh waters and the West England and Wales management unit (MU)?	NRW Q18

Annual reports are submitted to Defra on the implementation of Council Regulation (EC) No. 812/2004 and Council Directive 92/43/EE in relation to estimates of protected species bycatch.

Data on numbers of dolphins, porpoises and seals bycaught by ICES division are reported. The information for seals is given, the majority of which are grey seals. The overall estimate for 2013 was 391 (95% confidence limits 234, 1146) for the Irish and Celtic Seas and Channel (ICES subdivisions VIIa,d,e,f,g,h and j).

The best estimates for bycatch in the West England and Wales management unit are given in Table 11. The divisions shown in grey in the table are those that relate to the Irish Sea, English Channel, Bristol Channel and Celtic Sea. Overall estimates and confidence limits by metier are also given.

Table 11. ***Seal bycatch estimates by metier and by ICES Division***

STRATUM:	**Estimate**	**LCL**	**UCL**	**UCL-1-sided**
BY METIER				
Drift demersal	0	0	62	51
Drift pelagic	0	0	48	39
Gill	20	0.5	109	93
Gill hake	0	0	25	20
Gill light	0	0	268	217
Gill flatfish	61	2	337	287
Tangle Trammel	389	283	521	500
BY ICES DIVISION				
IVa	29	22	39	37
IVb	7	4	18	16
IVc	30	16	150	128
VIb	7	5	9	9
VIIa Irish Sea	**3**	**2**	**20**	**17**
VIId Eastern English Channel	**96**	**34**	**480**	**409**
VIIe Western English Channel	**139**	**92**	**343**	**306**
VIIf Bristol Channel	**108**	**75**	**208**	**190**
VIIg Celtic Sea North	**22**	**16**	**54**	**48**
VIIh Celtic Sea South	**14**	**9**	**25**	**23**
VIIj Southwest of Ireland	**9**	**6**	**16**	**14**
VIII	6	4	9	9
TOTALS	469 (CV=0.117)	285	1369	1206

Climate change

49. Is there any evidence of significant impacts on seal populations from climate change and are there practical adaptation measures that might be considered to alleviate these?	Defra Sec Q18

The potential impacts of climate change on marine mammals are not fully understood, but it is anticipated that they will be primarily affected by habitat loss and changes in prey distribution and abundance and consequential effects on health and disease. Further details of the impacts of climate change can be found in the Marine Climate Change Impacts Partnership Report Cards (http://www.mccip.org.uk/annual-report-card.aspx)

Disturbance

50. What recent research is there on the impacts to seals from visual disturbance (anthropogenic activity) and the recommended distances to maintain away from seals to avoid disturbance? Apart from underwater noise, what are the other main sources of disturbance for grey seals that are cause for concern and is there any evidence that these have adverse effects on grey seal populations? If there is an impact, are there new approaches (mitigation) to reducing the impact of such disturbance on seals?	Defra Sec Q20; NRW Q13

Research into the impact of disturbance on seals is continuing. Information on a study being carried out at SMRU was reported in SCOS 2013.

Marine Strategy Framework Directive

51. In light of the work being undertaken by OSPAR and others on the development of seal indicators and targets for determining Good Environmental Status (GES) under the Marine Strategy Framework Directive (MSFD) could the Committee evaluate the contribution and value of the work currently undertaken in the UK in meeting these requirements?	Defra Sec Q19

Population data to support the UK and OSPAR common seal targets and indicators for determining 'Good Environmental Status' under the Marine Strategy Framework Directive continue to be collected by SMRU. Grey seal pup production estimates and harbour seal and grey seal abundance during the harbour seal moult are updated an annual basis and reported to SCOS. These abundance data are in a format that could be readily analysed in relation to any of the current targets that are being discussed. However, data for the distribution pattern indicators, whilst also

readily available, are not currently reported to SCOS in a form that would be comparable to the suggested targets. This would need to be the case to make these indicators fully operational.

The work of OSPAR on the development of seal indicators and targets for determining GES has resulted in three indicators; M-1 Distributional range and pattern of grey and harbour seal breeding and haul-out sites; M-3 Abundance of grey and harbour seals at breeding and haul-out sites and M-5 Grey seal pup production. Further details of the development of these indicators and a discussion of the associated targets currently being considered are given in SCOS-BP 14/06. The data to support all three of these indicators and judge them against GES targets are in line with the population abundance and distribution data currently reported to SCOS. Thus the work currently undertaken by SMRU and with the additional contribution from other groups who supplement the dataset (with, for example, additional ground counts of grey seal pups born during the breeding season), will allow the UK to fulfil its obligations under MSFD. The data could be reported to OSPAR through ICES and ultimately fed into the UK Marine Strategy (Part Two) fulfilling the requirements of MSFD both at the UK and international levels. Since the requirements are well aligned with what is already being reported on through SCOS, the two abundance indicators would be readily addressed. However, some further work needs to be carried out on the distributional pattern indicators (see SCOS-BP 14/06 for details), but if the data in the form required was requested through SCOS, this could also be included in the annual advice provided by SMRU.

ANNEX I

NERC Special Committee on Seals

Terms of Reference

1. To undertake, on behalf of Council, the provision of scientific advice to the Scottish Government and the Home Office on questions relating to the status of grey and harbour seals in British waters and to their management, as required under the Conservation of Seals Act 1970, Marine Coastal and Access Act 2009 and the Marine (Scotland) Act 2010.

2. To comment on SMRU's core strategic research programme and other commissioned research, and to provide a wider perspective on scientific issues of importance, with respect to the provision of advice under Term of Reference 1.

3. To report to Council through the NERC Chief Executive.

Current membership

Professor D. Bowen (Chair),	Bedford Institute of Oceanography, Canada;
Dr A. Hall	SMRU, University of St Andrews;
Dr S. Wanless	CEH, Edinburgh;
Dr J. Forcada	British Antarctic Survey;
Dr K. Brookes	Marine Scotland, Science, Aberdeen;
Dr A. Bjørge	Institute of Marine Research, Bergen, Norway;
Dr C. Lynam	Cefas, Lowestoft;
Professor P. Thompson	University of Aberdeen;
Dr S. Piertney	University of Aberdeen;
Dr M. Hammill	Maurice Lamontage Institute, Canada;
Dr G. Truelove (Secretary)	NERC, Swindon Office.

ANNEX II

Questions from Marine Scotland

Dear Dr Truelove

MARINE (SCOTLAND) ACT 2010 (CONSEQUENTIAL PROVISIONS) ORDER 2010: ANNUAL REVIEW OF MANAGEMENT ADVICE

Thank you for your letter of 9 June 2014 concerning the next meeting of the Special Committee on Seals on 2 September 2014 and asking whether the Scottish Government has any specific questions on which it would welcome the Committee's scientific advice.

It would be very helpful if the Committee could provide a general update on seal populations and respond to some more specific questions on particular issues as set out below.

We have, as usual, structured our request for advice from the Committee in two broad categories. The first comprises a shorter than usual list of standard questions seeking a update on some of the key information regularly provided by the Committee in previous years:-

1. **What are the latest estimates of the number of seals in Scottish waters?**

2. **What is the latest information about the population structure, including survival and age structure, of grey and common/harbour seals in European and Scottish waters? Is there any new evidence of populations or sub-populations specific to local areas?**

Specific questions about improving seal management:-

Common/Harbour Seal Population

3. Is the existing common/harbour seal decline recorded in several local areas around Scotland continuing or not and what is the position in other areas?
4. In light of the latest reports, should the Scottish Government consider additional conservation measures to protect vulnerable local common/harbour seal populations in any additional areas to those already covered by seal conservation areas or should it consider removing existing conservation measures in any areas?
5. What is the latest understanding of the causes of the recent decline in common/harbour seals?
6. What potential mitigation measures might be useful to slow the decline or to assist recovery?
7. In those areas where a decline in common/harbour seal numbers has been recorded in recent years, given a business as usual scenario, what is the projected future population growth/decline?

Seal Diet

8. What are the key findings arising from the results of the current seal diet study for grey seals and for common seals?

Seals and Salmon Netting Stations

9. What is the current state of knowledge of interactions between seals and salmon netting stations and possible mitigation measures and what are the priority areas for research in terms of practical non-lethal options?

Seals and Fish Farms

10. What is the current state of knowledge of interactions between seals and fin fish farms and possible mitigation measures and what are the priority areas for research in terms of practical non-lethal options?

Seals and Marine Renewables

11. What is the current state of knowledge of interactions actual or potential between seals and marine renewable devices and possible mitigation measures?

12. What potential interactions can we rule out at this time in respect of specific types of renewable device, particular stages of their development (i.e. construction and operation) and seals?

13. What additional work might most effectively improve assessment of possible impacts of marine renewables on seal populations at regional and national level?

14. What progress is being made in understanding how seals behave around tidal turbine devices, including diving behaviour, and about what might be an appropriate avoidance rate to be applied in collision risk modelling?

15. What evidence exists about common/harbour seal range that might help to define possible areas of concern for specific marine renewable developments?

16. Can the resolution of current seal density maps be reduced (to 1 X 1 km) to take account of smaller development sites, which can be used in encounter risk models for specific marine renewable developments?

Seal Licensing and PBRs

17. What, if any, changes are suggested in the Permitted/Potential Biological Removals (PBRs) for use in relation to the seal licence system?

18. Is the PBR the best method for dealing with potential collision risk involving marine renewable turbines (recognising that collisions may not always be lethal) or is there another more appropriate framework that might be applied in such circumstances?

Unusual Seal Mortalities

19. What is the latest understanding of the causes of the recent unusual seal mortalities and of their potential impact on wider seal populations?

20. What is the latest position on possible mitigation measures?

21. What potential mechanisms can be ruled out as a result of trials to date?

Population Redistribution?

22. Is there any evidence for the redistribution of grey or common (harbour) seals in Scotland and, if so, what are the likely causes of such changes?

Designated Seal Haul-out Sites

23. In light of 194 seal haul-out sites around Scotland being designated to protect seals from harassment, how frequently does the committee consider it would be useful to review these sites to ensure their continued relevance for the seals and/or to add new or remove redundant sites?

As in previous years, it is our intention to publish a link to the advice provided by the Committee on the Scottish Government web-site. We will liaise about the timing of that in due course.

I also enclose the information requested on licences issued by the Scottish Government during 2013 under The Marine (Scotland) Act 2010. You will be aware that this Act has now replaced The Conservation of Seals Act (1970) in Scotland. This means that information on seal licences issued in Scotland will be presented in a different format, one that is considered more appropriate for the new seal licensing system. This information can be found on the Scottish Government web-site through the following link (see Tables 1, 2a and 2b):-

http://www.scotland.gov.uk/Topics/marine/Licensing/SealLicensing/2011/2013

I am copying this letter to Defra colleagues for information.

Questions from Defra

Dear Dr Truelove

CONSERVATION OF SEALS ACT 1970: ANNUAL REVIEW OF MANAGEMENT ADVICE

Thank you for your email letter of 9 June 2014, asking if Defra has any specific questions on which it wishes to receive scientific advice.

The following are standard questions which were asked in 2013 (these are based on questions previously asked by Scotland in relation to seals in Scottish waters) seeking a general update on information regularly provided by the Committee in previous years. It is understood that each devolved administration would ask similar questions so that a UK wide picture would be provided in the annual SCOS report.

1. What are the latest estimates of the number of seals in English waters?

2. What is known about the population structure, including survival and age structure, of grey and common seals in European and English waters?

3. Is there any evidence of populations or sub-populations specific to local areas within English waters?

4. What is the latest estimate of consumption of commercially important fish by seals in English waters?

5. Have there been any recent developments, in relation to non-lethal methods of population control, which mean that they could now effectively be applied to English seal populations where appropriate?

6. What are the latest results from satellite tagging in respect of usage of specific coastal and marine areas around England by grey and common seals and whether or not these suggest potential foraging sites?

7. Are there any disease outbreaks which are likely to have a significant impact on English seal populations within the next 12 months and, if so, what practical mitigation measures might be possible and appropriate?

The second category of questions comprises more specific questions and relates to improving seal management. Again, all but number 8 19 and 22 were asked last year, so anything to add to the advice given by SCOS in 2013 would be appreciated:-

Seal populations

1. What progress has been made in integrating grey seal population abundance models or selecting between these models using grey seal survey work undertaken in 2009?

2. What progress has been made in improving monitoring methods and abundance estimates of the common seal population?

3. Is the decline in common seal numbers in specific local areas continuing or not and what is the position in other areas?

4. What are the latest results from research investigating the causes of the recent decline in common seals and how has this improved understanding of potential causes?

5. What are the key questions about seal populations that remain to be addressed to better inform practical seal management issues?

Seal legislation

6. Does the Committee consider that there is a significant scientific requirement to change the current close seasons for each native seal species?

Seals and salmon netting stations

7. What research is currently available on interactions between seals and salmon netting stations and what new research might usefully be done in this area?

8. In the 2013 advice, you refer to net modifications made in 2012 which had a positive result in reducing seal impacts. Could you explain what those modifications were?

Seals and fish farms

9. What research is currently available on interactions between seals and fin fish farms and what new research might usefully be done in this area?

Occurrences of seals in fresh water in relation to seasonal salmon runs

10. What is the regularity of such an occurrence?

11. Where are the common freshwater locations of such occurrences?

12. What are effective deterrents in such freshwater locations?

13. What damage to salmon stocks is there as a result of seals in fresh water?

Management – We would be especially interested in receiving the results of research into deterrents

14. What information, if any, do you have on numbers of complaints of seal damage in England?

15. What information, if any, do you have on seals being killed in England to prevent damage to fisheries during the 'open seasons'?

The same information for Scotland and Wales would also be of interest if not available for England or for comparison with figures from England. MSA seal licence returns from Scotland were available for SCOS 2012.

16. What information, if any, do you have on seals being killed under the 'fisherman's defence' provided by s.9(1)(c) of the 1970 Act?

Shooting

17. How effective are the current firearm and ammunition minima stipulated in the act in relation to the termination of a seal?

Climate change

18. Is there any evidence of significant impacts on seal populations from climate change and are there practical adaptation measures that might be considered to alleviate these?

Marine Strategy Framework Directive

19. In light of the work being undertaken OSPAR and others on the development of seal indicators and targets for determining Good Environmental Status (GES) under the Marine Strategy Framework Directive (MSFD), could the Committee evaluate the contribution and value of the work currently undertaken in the UK in meeting these requirements.

Disturbance

20. What recent research is there on the impacts to seals from visual and other disturbance (anthropogenic activity) and the recommended distances to maintain away from seals to avoid disturbance?

Unusual seal mortalities

21. What is the latest understanding of the causes of the recent unusual seal mortalities and of their potential impact on wider seal populations?

22. Are you aware of any grey seal predation on common seal in UK waters?

I hope this satisfies your requirements. If you have any queries about this letter please contact me.

Questions from Natural Resources, Wales

Dear Dr Truelove

CONSERVATION OF SEALS ACT (1970): ANNUAL REVIEW OF MANAGEMENT ADVICE

Thank you for your email of 9 June 2014 to ask if Natural Resources Wales (NRW) has any specific questions on which it wishes to receive scientific advice.

It would be very helpful if the Committee could provide an update on seal populations and anthropogenic interactions in the West England and Wales management unit (MU). To aid this update, some specific questions have been outlined below.

Population structuring, abundance and movements

1. What are the latest estimates of the number of seals in Welsh waters and the West England and Wales management unit (MU)?
2. What is the latest information about population structure, including survival, age, and fecundity, of grey seals in European and Welsh waters?
3. Are there likely to be any substantial regional differences in grey seal demographics? Is there any new evidence of subpopulations/population structure in Welsh waters compared to the rest of UK?
4. Is there any evidence of population structuring specifically through genetic differentiation and stable isotope profiles among seals in Welsh waters, the West England and Wales management unit (MU), and the rest of NE European waters?
5. What is the latest information on grey seal movements (satellite tracking or photoID) between colonies in Wales, the West England and Wales management unit (MU), other regions in the UK, Ireland and France?
6. Is there any evidence that seals move between protected sites (e.g. SACs, SSSIs) and have any routine movement passages been identified?
7. What are the median, mean, max and 95% CIs of travel distances of grey seals that have been satellite tracked in the West England and Wales management unit (MU) and surrounding waters? Such distance metrics might be used, within each MU, to provide distances within which SACs and developments should be considered for impact assessments.

Management Units (IAMMWG and ICES MUs) and impact assessments

8. Do the seal MUs adequately define the ‘populations’ against which impacts should be assessed?
9. What is the degree of interchange and connectivity between MUs and how does this affect the biological validity of defining MU populations?
10. How should developments that border several MUs apportion their impacts on the ‘populations’ in these MUs?
11. Can we apportion impacts identified within defined management units to specific SAC ‘populations/assemblages’?
12. What evidence is available that construction noise from marine developments, eg from piling, deters seals from ensonified areas and are potential noise ‘barriers’ likely to have adverse impacts on grey seal populations?
13. Apart from underwater noise, what are the other main sources of disturbance for grey seals that are cause for concern and is there any evidence that these have adverse effects on

grey seal populations? If there is an impact, are there new approaches (mitigation) to reducing the impact of such disturbance on seals?

14. There is a philosophical difference between an impact / change that is detectable and that which is acceptable. What do SCOS think is an appropriate threshold for acceptable impact / change, e.g. mortality / auditory injury / displacement, in seal populations (within MUs) and should this be equitable to established guidelines in other taxa, e.g. FCS (1%), IWC bycatch (1.7%)?

Diet

15. What is the latest information on grey seal diet around the UK and does it differ regionally, with particular emphasis on SW Britain?

Marine renewables

16. What is the current knowledge of interactions between seals and wet renewable (tidal turbine) devices?
17. What is the current thought on suitable mitigation measures for reducing collision risk with turbines in strong tidal conditions?

Bycatch

18. What are the best estimates of the level of seal mortality from bycatch in Welsh waters and the West England and Wales management unit (MU)?

Unusual seal mortalities

19. What is the latest understanding of the causes of ‘corkscrew’ injuries and likely impacts of these injuries at the population level, with particular emphasis on occurrences of strandings that indicate these injuries in the West England and Wales management unit (MU)?
20. What is the latest position on possible mitigation measures for minimising ‘corkscrew’ injuries?

Occurrence of grey seals in freshwater

21. What is the current state of knowledge on the occurrence of grey seals in freshwater in SW Britain? Where in the UK is this also known to occur and is there any information on seasonal occurrence of such behaviour?
22. What information, if any, is there on predation levels of salmon by grey seals in SW Britain and Welsh waters?

Many thanks for your consideration, it is very much appreciated

ANNEX III

Briefing Papers for SCOS

The following Briefing papers are included to ensure that the science underpinning the SCOS Advice is available in sufficient detail. Briefing papers provide up-to-date information from the scientists involved in the research and are attributed to those scientists. Briefing papers do no replace fully published papers. Instead, they are an opportunity for SCOS to consider both completed work and work in progress. It is also intended that current Briefing papers should represent a record of work that can be carried forward to future meetings of SCOS.

L

ist of briefing papers appended to the SCOS Advice, 2014

14/01 Grey seal pup production in Britain in 2012: First complete survey using a digital system

Duck, C.D. and Morris, C.D.

14/02 Estimating the size of the UK grey seal population between 1984 and 2013, using established and draft revised priors

Thomas, L.

14/03 The status of UK harbour seal populations in 2013, including summer counts of grey seals

Duck, C.D., Morris, C.D. and Thompson, D.

14/04 Colony specific implications of individual mass changes for survival and fecundity in female grey seals (*Halichoerus grypus).*

Smout, S. King R. and Pomeroy P.

14/05 Provisional Regional PBR values for Scottish seals in 2015

Thompson, D., Morris C.D. and. Duck C.D.

14/06 Seal targets and indicators for determining Good Environmental Status under the Marine Strategy Framework Directive

Hall, A.J., Pinn, E., Weinberg, J. and Mitchell, I.

Grey seal pup production in Britain in 2012: First complete survey using a digital system

Callan D. Duck and Chris D. Morris

Sea Mammal Research Unit, Scottish Oceans Institute, University of St Andrews, St Andrews KY16 8LB

Abstract

In the 2012 grey seal breeding season, SMRU developed and used a new, digital photographic system to survey the main grey seal breeding colonies in Scotland. A NERC equipment grant enabled transfer from the Linhof AeroTechica film camera, used since 1985, to a twin Hasselblad H4D digital system. The cameras were mounted in the existing, but modified, Image Motion Compensating cradle which reduces ground movement as the camera shutters fire. This results in sharper images, particularly in low light conditions.

The resulting digital images were of significantly improved resolution (approximately 2.5 cm/pixel) compared with the film used previously, resulting in (hopefully) more accurate categorization and counts of pups. Considerable processing of the images was required prior to counting, including: brightness and sharpness adjustment, perspective correction and stitching individual frames to create a single high-resolution image of each breeding colony.

Because of differences in ground cover per single frame between the large-format Linhof camera and the medium format Hasselblad cameras, the digital system produced approximately 20,000 images from a complete survey of approximately 60 breeding colonies, compared with approximately 6,000 frames produced by the Linhof system.

Grey seal pup production at annually monitored UK breeding colonies in 2012 was estimated to be **51,323** compared with 44,904 in 2010, an average annual increase on 6.9%. Including colonies monitored less frequently, pup production in 2012 was estimated to be **56,988** compared with 50,203 in 2010, an average annual increase of 6.5% over two years.

Pup production at 12 colonies in the Inner Hebrides in 2012 was **4,088** compared with 3,391 in 2010, an average annual increase of 9.0% (one new colony producing 90 pups was included in 2012). This was very different to the average annual change estimated for the 2006-2012 period which was 3.1%, and the first time that pup production in the Inner Hebrides exceeded 4,000.

Pup production at 15 colonies in the Outer Hebrides was **14,136** compared with 12,857 in 2010, an average annual increase of 4.9%.

Pup production at 26 colonies in Orkney was **22,926** in 2012 compared with 20,312 in 2010, an average annual increase of 6.2%.

At the seven North Sea colonies, pup production in 2012 was **10,173** compared with 8,314 in 2010, an average annual increase of 10.3%. Within the North Sea group, production at colonies in the Firth of Forth was **5,210** compared with 4,279 in 2010, an average annual increase of 10.4%. Pup production at colonies in east England in 2012 was **4,963** compared with 4,065 in 2010, an annual increase of 10.5%.

Introduction

Grey seals breed at traditional colonies, with females frequently returning to the same colony to breed in successive years (Pomeroy *et al*. 2001). Some females return to breed at the colony at which they were born. Habitual use by grey seals of specific breeding colonies, combined with knowledge of the location of those colonies, provides opportunity for the numbers of pups born at the colonies to be monitored.

While grey seals breed all around the UK coast, most (approximately 85%) breed at colonies in Scotland (Figure 1). Other main breeding colonies are along the east coast of England, in south-west England and in Wales. Most colonies in Scotland and east England are on remote coasts or remote off-lying islands. Breeding colonies in south-west England and in Wales are either at the foot of steep cliffs or in caves and are therefore extremely difficult to monitor.

Until 2010, SMRU conducted annual aerial surveys of the major grey seal breeding colonies in Scotland to determine the number of pups born. The number of pups born at colonies along the east coast of England is monitored annually by counting on the ground by different organisations: National Trust staff count pups born at the Farne Islands (Northumberland) and at Blakeney Point (Norfolk); staff from the Lincolnshire Wildlife Trust count pups born at Donna Nook and staff from Natural England count pups born at Horsey/Winterton, on the east Norfolk coast. Scottish Natural Heritage (SNH) staff ground counted grey seal pups born in Shetland and on South Ronaldsay in Orkney.

Reductions in funding, combined with increasing aerial survey costs, have resulted in SMRU moving from monitoring grey seal breeding colonies annually to a biennial survey regime. The first year with no survey was 2011. In 2012, a new digital camera system, funded by NERC, replaced the film-based large-format Linhof AeroTechnika system that has been in use since 1985. The same 60 colonies were surveyed either four or five times, at approximately 10 to 12 day intervals, through the breeding season. Increased numbers of images acquired during a full survey (20,000 digital images compared with 6,000 frames) and the development of an image processing procedure prior to counting, resulted in a delay in completing estimating pup production at all 60 colonies. For SCOS 2013, only images from all surveys of colonies in the Inner Hebrides and the Firth of Forth had been completed, as well as from one survey of Ceann Iar, in the Monach Isles in the Outer Hebrides.

This Briefing Paper reports the full results of the 2012 grey seal pup surveys, including a comparison with pup production at the surveyed colonies in previous years.

Materials and Methods

SMRU aerially surveys the main breeding colonies around Scotland. Pups born at colonies in England are counted from the ground annually by staff from the National Trust (Farne Islands and Blakeney Point), Lincolnshire Wildlife Trust (Donna Nook) and Natural England (Horsey/Winterton) and by SNH (Shetland).

The numbers of pups born (pup production) at the aerially surveyed colonies in Scotland is estimated from a series of 3 or 5 counts derived from aerial images using a model of the birth process and the development of pups. The method used to obtain pup production estimates in 2012 was similar to that used in previous years. A lognormal distribution was fitted to colonies surveyed four or more times and a normal distribution to colonies surveyed three times.

Between four and five surveys of the main grey seal breeding colonies in Scotland were carried out between September and November 2012. Paired digital images were obtained from two Hasselblad H4D 40MP cameras mounted at opposing angles of 12 degrees from vertical in SMRU's modified Image Motion Compensating cradle (Figure 2). As previously, a series of transects were flown over each breeding colony, ensuring that all areas used by pups were photographed (Figures 3 and 4). Images were recorded directly onto hard drives, one for each camera. Hard drives were downloaded and backed up after each day's survey.

All images were first adjusted for brightness and sharpness using Hasselblad's image processing software, Phocus. Individual images were then stretched from rectangular to trapezoid to closely match the ground area covered by oblique photographs taken at an angle of 12 degrees (Figure 3). All perspective-corrected images covering one survey of a particular colony were then stitched together to create a single digital image of the entire colony up to 15GB in size. Images were stitched and exported as PSB files using Microsoft's Image Composite Editor v1.4.4. In a few cases where the stitching software could not stitch all images, such as with images of areas with large differences in ground elevation, images were stitched or adjusted manually using Adobe Photoshop CS5. The final composites were then saved as LZW compressed TIFF files (large images were split if TIFF's 4GB maximum file size was exceeded) and imported into Manifold GIS 8.0 for counting. The imported images were compressed within Manifold to reduce file size without losing too much image detail. Separate layers were created for marking whitecoat, moulted and dead pups (Figures 5 and 6). As part of the process of learning how to manipulate and counts pups on the digital images, adult seals were also counted. These data may prove useful for other studies and are not reported here.

Previously, because there was a significant risk of misclassifying moulted pups as whitecoats, the pup production model used a fixed value of 50% for the proportion of correctly classified moulted pups. Pups spend a lot of time lying on their back or side and, depending on light conditions during a survey, it is possible to misclassify a moulted pup exposing its white belly as a whitecoat. Misclassification of a whitecoat as a moulted pup is considerably less likely.

The pup production model allows different misclassification proportions to be used. In Shetland, where pups are counted from the tops of cliffs and misclassification of moulted pups is likely to be low, a correctly classified proportion of 90% was used (SCOS-BP 05/01).

The digital images were of sufficient quality to reduce misclassification, so a proportion of 90% was used as standard for all production estimates.

Results

The locations of the main grey seal breeding colonies in the UK are shown in Figure 1. In 2012, 51,293 pups were born at all annually monitored colonies compared with 44,874 in 2010, an annual increase of 6.9% over the two years (Figure 7). The contribution to overall pup production from the annually monitored main 'island' groups since 1960 is shown in Figure 8. The change in UK grey seal pup production between 2010 and 2012 (point to point), between 2001 and 2006 as well as between 2006 and 2012 (from the regression of $\log_{10}$(production)) are given in Table 1. The time series of pup production since 1960 at the four annually monitored 'island' groups is in Table 2. Pup production trajectories since 1984 for the Inner Hebrides, Outer Hebrides and for Orkney, with 95% confidence intervals are shown in Figure 9(a). Production trajectories for the North Sea colonies are shown in Figure 9(b), with 95% confidence intervals where available.

In Scotland, 46,360 pups were born at annually monitored colonies in 2012 with 3,665 pups born at other Scottish colonies (Tables 1, 3 and 4).

In England, 4,963 pups were born at the annually monitored colonies on the east coast, with an estimated 250 pups born in the West Country, Lundy and the Isles of Scilly. Grey seals breeding in west England and in Wales are extremely difficult to survey as many colonies are in caves.

In Wales, the breeding colonies on Skomer and Ramsey Island are monitored annually while the remaining colonies in Pembrokeshire and in North Wales are monitored considerably less frequently. Many colonies are in caves and are difficult to access during the autumn breeding season. An estimated 1,650 pups are born in Wales.

In Northern Ireland, an estimated 100 pups are born in Strangford Lough and on islands off the east coast of the Ards Peninsula (Table 1).

Combining all production estimates from across the UK gives a total of 56,988 grey seal pups born in 2012, compared with 50,203 born in 2010, an average annual increase of 6.5% (Table 1).

Pup production at colonies in the Inner Hebrides in 2012

Pup production at colonies in the Inner Hebrides increased at an average annual rate of 9.8% between 2010 (3,391) and 2012 (4,088; Table 1). This was the first occasion that pup production at the 12 colonies in the Inner Hebrides exceeded 4,000 (Figure 9a, Table 1). The trend in production was not consistent at all colonies, with some increasing some remaining more or less stable and a small number declining. The five colonies around north Islay and Colonsay increased more rapidly than the two colonies close to Coll (Figure 10) while the five colonies around the Treshnish Isles (an SAC) showed a slight decline until 2012.

Pup production at colonies in the Outer Hebrides in 2012

At colonies in the Outer Hebrides, pup production increased from 12,857 in 2010 to 14,136 in 2012, an average annual increase of 4.9% over two years (Table 1, Figure 9a). Figure 11 compares pup production at long established colonies (Old) with colonies in the Monach Isles (colonised in the late 1960s and early 1970s) and colonies established since the late 1990s (New). Overall, the combined production at the six old colonies has declined constantly since the early 1990s while it has increased at the five Monach Isles colonies and at the six recently established colonies south of Barra. Within each of these colony groups, there was variation in the production trajectories of individual colonies.

Pup production at colonies in Orkney in 2012

Pup production at colonies in Orkney increased from 20,312 in 2010 to 22,926 in 2012, an average annual increase of 6.2%. Production at the eight oldest colonies (pre-1970s) in Orkney has remained relatively constant since the late 1980s (Figure 12), while it has constantly increased at nine colonies established during or close to the 1970s. Production at nine new colonies (established since early 1990s) initially increased, levelled off between 2004 and 2010, before increasing in 2012.

Pup production at North Sea colonies in 2012

Grey seal pup production estimates increased at all breeding colonies in the North Sea group (Table 1, Figure 9). Pup production at colonies in the Firth of Forth was 5,210 in 2012 and 4,279 in 2010, an average annual increase of 10.3% (including 30 pups born at Craigleith from 2009). The Farne Islands produced 1,603 pups in 2012 and 1,499 in 2010, an average annual increase of 3.4%. At colonies between the Humber Estuary and Great Yarmouth, 3,360 pups were born in 2012 compared with 2,566 in 2010, an average annual increase of 14.4%. The pup production increases at these three groups of colonies in the North Sea are similar to the 6-year trend between 2006 and 2012 and the 5-year tend between 2002 and 2006, varying between 14% and 15% (Table 1). Collectively, the three colonies in south-east England, Donna Nook, Blakeney Point and Horsey (Figure 1) are the most rapidly increasing in the UK, although the increase at Donna Nook has been slowing in recent years.

Discussion

Overall, grey seal pup production in 2012 increased at all the main island groups compared with production in 2010. However, pup production did not increase at all individual colonies within the island groups. In the Inner Hebrides, Outer Hebrides and in Orkney island groups there were individual colonies where production declined. In the Outer Hebrides, colonies in decline had been established the longest (Figure 11).

It was not immediately clear whether increases in pup production were a consequence of the new digital photographic system or whether they reflect actual changes in pup production. Increases at the colonies surveyed aerially by SMRU in the Firth of Forth were comparable to increases at the remaining North Sea colonies in England which are surveyed by very different methods – by counting pups from the ground. Furthermore, the average annual increases were consistent with the average increase over the previous 5-year interval (Table 1, Figure 9b).

The digital images were mostly of high quality; a small number of images were blurred due to aircraft movement coinciding with camera shutters firing. One obvious benefit of the increased image resolution was that pups could be more accurately classified into whitecoated, moulted or dead categories. Following previous investigations into the difference made to production estimates by varying the proportion of correctly classified moulted pups (Duck & Morris 2013),

Without running parallel surveys using the two imaging systems a direct comparison of the two survey systems is difficult. Given that surveys are now biennial rather than annual, due to reductions in SMRU core funding, it was not financially possible to conduct a simultaneous test of the two systems.

There are many advantages of the new digital system. The one disadvantage is the increase in the time required for processing images before they can be loaded into a GIS for counting. As it now takes longer than previously to process some colonies but less time to process others, time will tell whether the new system requires more or less time overall than the old system. Ultimately, however, the digital system should allow individual seals (pups and adults) to be geo-referenced within each colony, thus creating new opportunities for additional data analyses.

Conclusions

The new digital camera system produced images with considerably improved resolution. It took a significant amount of time to develop a new method for processing and preparing the digital images for counting; the time required should reduce in future years, now that the methodology is in place.

Grey seal pup production in 2012 at annually monitored colonies increased from 44,904 in 2010 to 51,323 in 2012. The increase in pup production at North Sea colonies in the Firth of Forth that were aerially surveyed with the new digital system showed increases that were comparable to North Sea colonies in east England that were ground counted. These increases continued the 6-year trend observed between 2006 and 2012.

Grey seal pup production at colonies in the Inner Hebrides showed an average annual increase of 9% since 2010. This is a significant change following several years of very little or no increase.

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Table 1. Grey seal pup production estimates from 2012 compared with production estimates from 2010 and preceding five-year intervals. The average annual change for the multi-year intervals are the slope of the regression of the $\log_{10}$ (pup production) over the relevant period; for annually monitored colonies only.

Location	Pup production in **2012**	Average annual change 2010 to **2012**	Pup production in 2010	Average annual change 2001 and 2006	Average annual change 2006 to **2012**
Inner Hebrides	4,088	+9.8%	3,391	+2.8%	+3.1%
Outer Hebrides	14,136	+4.9%	12,857	+0.1%	+3.3%
Orkney	22,926	+6.2%	20,312	+0.1%	+3.0%
Firth of Forth	5,210	+10.3%	4,279	+3.9%	+11.6%
Annually monitored colonies in Scotland	46,360	+6.5%	40,839	+1.0%	+3.9%
Other Scottish colonies [1] (incl. Shetland & mainland)	3,665 [1]	+5.4%	3,299 [1]		
Total Scotland	**50,025**	+6.5%	**44,138**		
Donna Nook +East Anglia	3,360	+14.4%	2,566	+15.6%	+15.1%
Farne Islands	1,603	+3.4%	1,499	+0.7%	+5.1%
Annually monitored colonies in England	4,963	+10.5%	4,065	+7.0%	+11.2%
SW England (last surveyed 1994)	250 est		250 est		
Wales [2]	1,650 est		1,650 est		
Total England & Wales	**6,863**	**+7.3%**	**5,965**		
Northern Ireland	100 est		100 est		
Total UK	**56,988**	**+6.5%**	**50,203**		

[1] Estimates derived from data collected in different years

[2] Estimates from indicator sites in 2004-05, multiplier derived from 1994 synoptic surveys

Table 2. Estimates of grey seal pup production from annually surveyed colonies in the Inner and Outer Hebrides, Orkney and the North Sea between 1960 and 2012.

YEAR	Inner Hebrides	Outer Hebrides	Orkney	North Sea	Total
1960			2048	1020	
1961		3142	1846	1141	
1962				1118	
1963				1259	
1964			2048	1439	
1965			2191	1404	
1966		3311	2287	1728	7326
1967		3265	2390	1779	7434
1968		3421	2570	1800	7791
1969			2316	1919	
1970		5070	2535	2002	9607
1971			2766	2042	
1972		4933		1617	
1973			2581	1678	
1974		6173	2700	1668	10541
1975		6946	2679	1617	11242
1976		7147	3247	1426	11820
1977			3364	1243	
1978		6243	3778	1162	11183
1979		6670	3971	1620	12261
1980		8026	4476	1617	14119
1981		8086	5064	1531	14681
1982		7763	5241	1637	
1983				1238	
1984	1332	7594	4741	1325	14992
1985	1190	8165	5199	1711	16265
1986	1711	8455	5796	1834	17796
1987	2002	8777	6389	1867	19035
1988	1960	8689	5948	1474	18071
1989	1956	9275	6773	1922	19926
1990	2032	9801	6982	2278	21093
1991	2411	10617	8412	2375	23815
1992	2816	12215	9608	2437	27075
1993	2923	11915	10790	2710	28338
1994	2719	12054	11593	2652	29018
1995	3050	12713	12412	2757	30932
1996	3117	13176	14273[1]	2938	33504[1]
1997	3076	11946	14051	3698	32771
1998	3087	12434[2]	16367	3989	35877[2]
1999	2787	11759	15462	3380	33388
2000	3223	13396	16281	4303	37210
2001	3032[3]	12427	17938	4134	37531[3]
2002	3096	11248	17942[4]	4520[4]	36816[4]
2003	3386	12741[5]	18652[5]	4805[5]	39584[5]

YEAR	Inner Hebrides	Outer Hebrides	Orkney	North Sea	Total
2004	3385	12319	19123[3]	4921	39748
2005	3387	12297[6]	17644[6]	5132	38460
2006	3461	11719	19332	5322	39727
2007	3071	11342	18952	5560	38772
2008	3396	12712	18765[7]	6617	41450
2009	3396[8]	12113[8]	19150	7637[8]	42296
2010	3391	12857	20312	8314	44874
2011					
2012	4088	14136	22926	10143	51293
2013					

[1]Calf of Flotta included with Orkney total from 1996

[2]Berneray and Fiaray (off Barra) included in the Outer Hebrides total from 1998

[3]Oronsay included with Inner Hebrides from 2001

[4]South Ronaldsay included in the Orkney total; Blakeney Point and Horsey (both Norfolk) included with North Sea from 2002

[5]North Flotta, South Westray, Sule Skerry included with Orkney; Mingulay included with Outer Hebrides from 2003

[6]Pabbay included with Outer Hebrides; Rothiesholm (Stronsay) included with Orkney from 2005

[7]New colony on Hoy included with Orkney from 2008

[8]2008 production estimates were used as a proxy for all colonies in the Inner Hebrides and for 7 colonies in the Outer Hebrides for which new production estimates could not be derived. Oronsay Strand included with Inner Hebrides; Inchkeith included with North Sea.

Table 3. Scottish grey seal breeding colonies that are not surveyed annually and/or have recently been included in the survey programme. Most recent counts are in bold type. New colonies on Soa, off Coll and Sandray, south of Barra are included for the first time.

Island group	Location	Survey type	Last surveyed	Last surveyed	Recent pup count	Most recent count
Inner Hebrides	LochTarbert, Jura	SMRU visual	2007	2003, 2007	10, **4**	4
	West coast Islay	SMRU visual	2008	1998, every 3-4 years	None seen	0
	Ross of Mull, south coast	SMRU visual	2005	1998, infrequent	None seen	0
	Treshnish small islands	SMRU photo & vis	2010	annual	~**20** in total	20
	Staffa	SMRU visual	2008	1998, every other year	~**5**	5
	Little Colonsay, by Ulva	SMRU visual	2008	1998, every 3-4 years	**6**	6
	Meisgeir, Mull	SMRU visual	2008	1998, every 3-4 years	**1**	1
	Craig Inish, Tiree	SMRU photo	2005	1998, every 2-3 years	**2**	2
	Cairns of Coll	SMRU photo	2008	2003, 2007	22, **10**	10
annual	Soa, Coll	SMRU photo		2010	annual, with Inner Hebrides	
	Muck	SMRU photo	2005	1998, 2005	36, **18**	18
	Rum	SNH ground	2013	2005, annual	10-15	15
	Canna	SMRU photo	2005	2002, 2005	54, **25**	25
	Rona (Skye)	SMRU visual	2003	1989, infrequent	None seen	0
	Ascrib Islands, Skye	SMRU photo	2008	2002, 2005, 2007, 2008	60, 64, 42, **64**	64
	Fladda Chuain, North Skye	SMRU photo	2008	2005, 2007, 2008	73, 43, **129**	129
	Trodday, NE Skye	SMRU photo	2008	2008new	**55**	55
	Heisgeir, Dubh Artach, Skerryvore	SMRU visual	2003	1995, 1989, infrequent	None	0
Outer Hebrides	Sound of Harris islands	SMRU photo	2008	2002, 2005, 2007, 2008	358, 396, (194)[2], **296**	296
annual	Sandray, S of Barra	SMRU photo		2010	annual , with Ohebs	0
	St Kilda	NTS reports	rare	Infrequent	Few pups are born	5
	Shiants	SMRU visual	2008	1998, every other year	None	0
	Flannans	SMRU visual	2000	1994, every 2-3 years	None	0
	Bernera, Lewis	SMRU visual	1991	1991, infrequent	None seen	0
	Summer Isles	SMRU photo	2010	2002, 2003, 2005-2008, 2010	50, 58, 67, 69,25, **73** , 29	73
	Islands close to Handa	SMRU visual	2009	2002	**10**	10
	Faraid Head	SMRU visual	1998	1989, infrequent	None seen	0
	Eilean Hoan, Loch Eriboll	SMRU visual	2006	1998, annual	None	0
	Rabbit Island, Tongue	SMRU visual	2006	2002, every other year	None seen	0
Orkney	Sanday, Point of Spurness	digicam	2013	2002, 2004, 2005-2008, 2010	10, 27,34, 21,8,17, **0**	15
	Sanday, east and north	SMRU visual	2003	1994, every 2-3 years	None seen	0
	Papa Stronsay	SMRU visual	2009	1993, every 3-4 years	None seen	0
	Holm of Papa, Westray	SMRU visual	2009	1993, every 3-4 years	None seen	0
	North Ronaldsay	SMRU visual	2006	1994, every 2-3 years	None seen	0
	Eday mainland	SMRU photo	2010	2000, 2002	8, **2**	2
Others	Small Firth of Forth islands	Fife Seal Group	2012	Infrequent, 1997	<10, 4	5
Total	Small colonies (above)	Various			868	**759**
	Mainland Scotland	SMRU annual	2008, 2012			**2,145**
	Shetland	SNH ground	2012			**761**
Total	**Other Scottish colonies**		**to 2012**			**3,665**

Table 4. Pup production estimates or maximum pup counts for grey seal colonies in Shetland from 2004 to 2012. Frequent severe gales in 2005 restricted the opportunity to count and probably removed significant numbers of pups from some of the breeding beaches. The estimated pup productions for Uyea in 2005 and 2006 are clearly underestimates as only those breeding on beaches that were visible from the mainland could be counted. These data were collected by SNH staff (assisted by SMRU in 2004), and a team of hardy volunteers. Numbers in bold type were summed to give the 2012 production estimates. Numbers in shaded boxed are modelled estimates from a series of counts, numbers in red italics are maximum counts.

Shetland colony	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Papa Stour	196	135	153	168	*107*	*88*	no count	127	**132**
Dale of Walls	66	43	*18*	*36*	*10*	33	**27**	*24*	*21*
Muckle Roe	**23**	no count	no count	no count	no count	no count	no count	*4*	no count
Rona's Voe	106	83	50	57	*45*	82	76	**58**	*29*
Mousa	140	117	156	128	*122*	178	130	*33*	**164**
Fetlar	50	**32**	*21*	*23*	no count	*10*	no count	no count	no count
Whalsey Islands	*102*	72	77	103	119	95	56	*91*	**79**
South Havra	***4***	no count	no count	no count	no count	no count	no count	no count	no count
Fitful Head	*18*	no count	no count	no count	no count	no count	no count	***7***	no count
Uyea (N. Mainland)	*238*	*122*	*114*	*101*	*69*	**215**	*41*	*71*	*140*
NE Unst	no count	no count	no count	***3***	no count	no count	no count	no count	no count
Hermaness	no count	no count	no count	no count	no count	no count	no count	***9***	no count
Noss	no count	no count	no count	***2***	no count	no count	no count	no count	no count
Half Gruney	no count	no count	no count	no count	no count	no count	*9*	no count	***6***
Total max counts for year	*362*	*122*	*153*	*165*	*353*	*98*	*50*	*239*	*196*
Modelled total for year	581	482	436	456	119	603	289	185	375
Estimated pup production	**943**	**765**	**794**	**819**	**835**	**853**	**763**	**702**	**761**

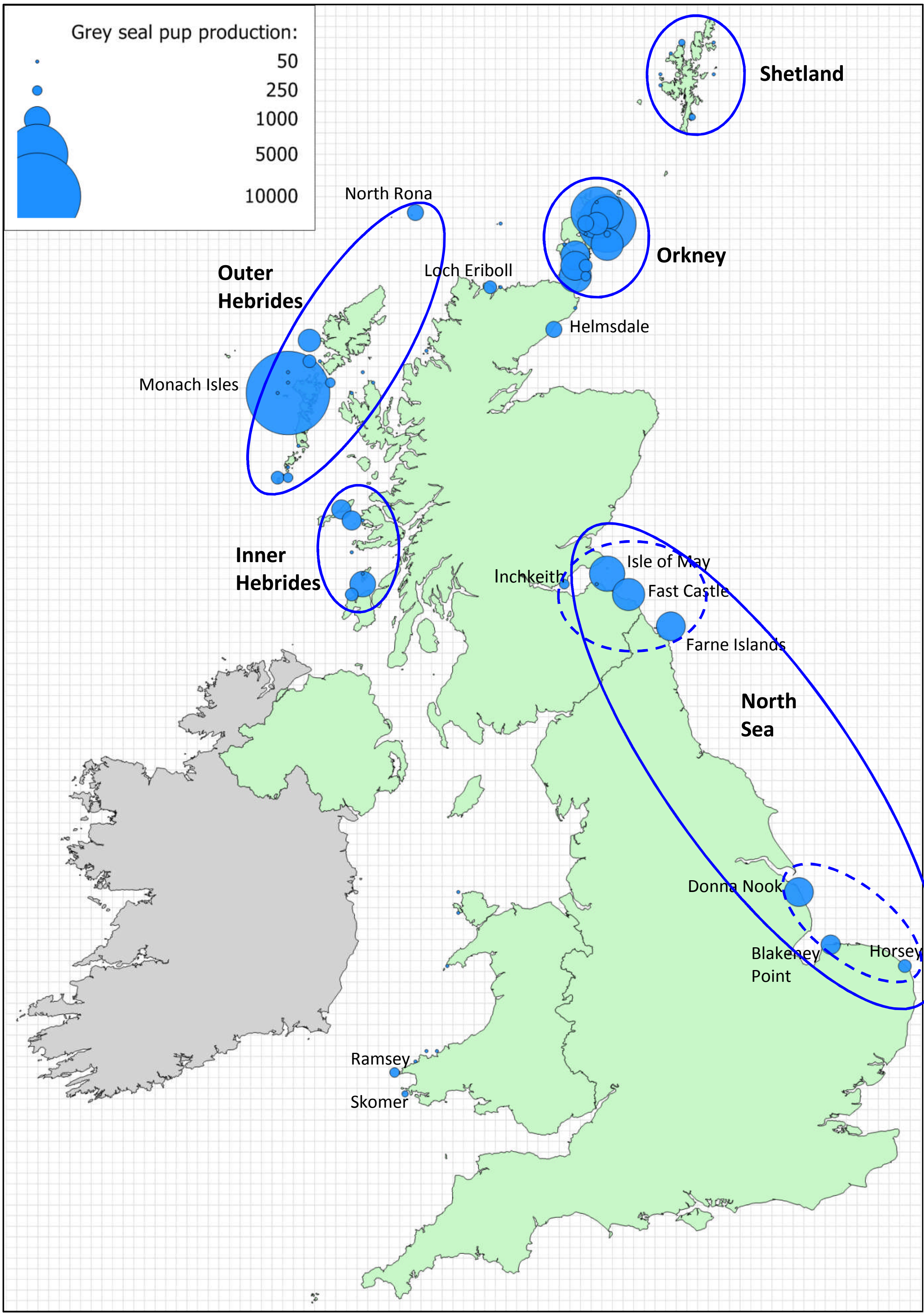


Figure 1. Pup production at the main grey seal breeding colonies in the UK at a 10km resolution. Smaller numbers of grey seals will breed at locations other than those indicated here, including in caves.

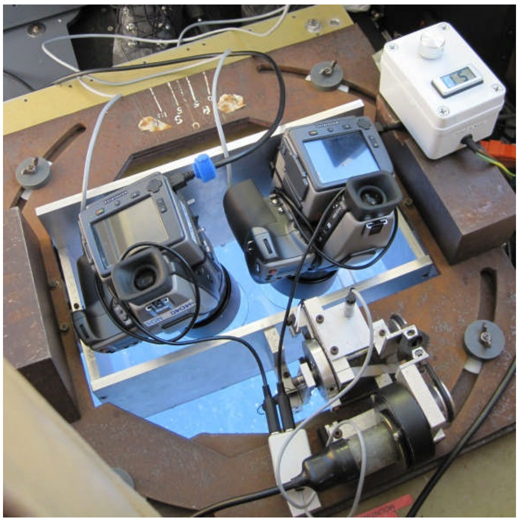


Figure 2. Two Hasselblad H4D-40 medium format cameras fitted in SMRU's Image Motion Compensation (IMC) mount. Each camera is set at an angle of 12 degrees to increase strip width. The cradle holding the cameras rocks backwards and forwards during photo runs. Rocking speed is set depending on the altitude and the ground speed of the aircraft. The camera shutters are automatically triggered and an image captured every time the cameras pass through the vertical position on each front-to-back pass. Images are saved directly to a computer as 60MB Hasselblad raw files and can be instantly viewed and checked using a small LED screen. The H4D-40 can take up to 40 frames per minute allowing for ground speeds of up to 140kts at 1100ft (providing 20% overlap between consecutive frames). The resulting ground sampling distance is approximately 2.5 cm/pix.

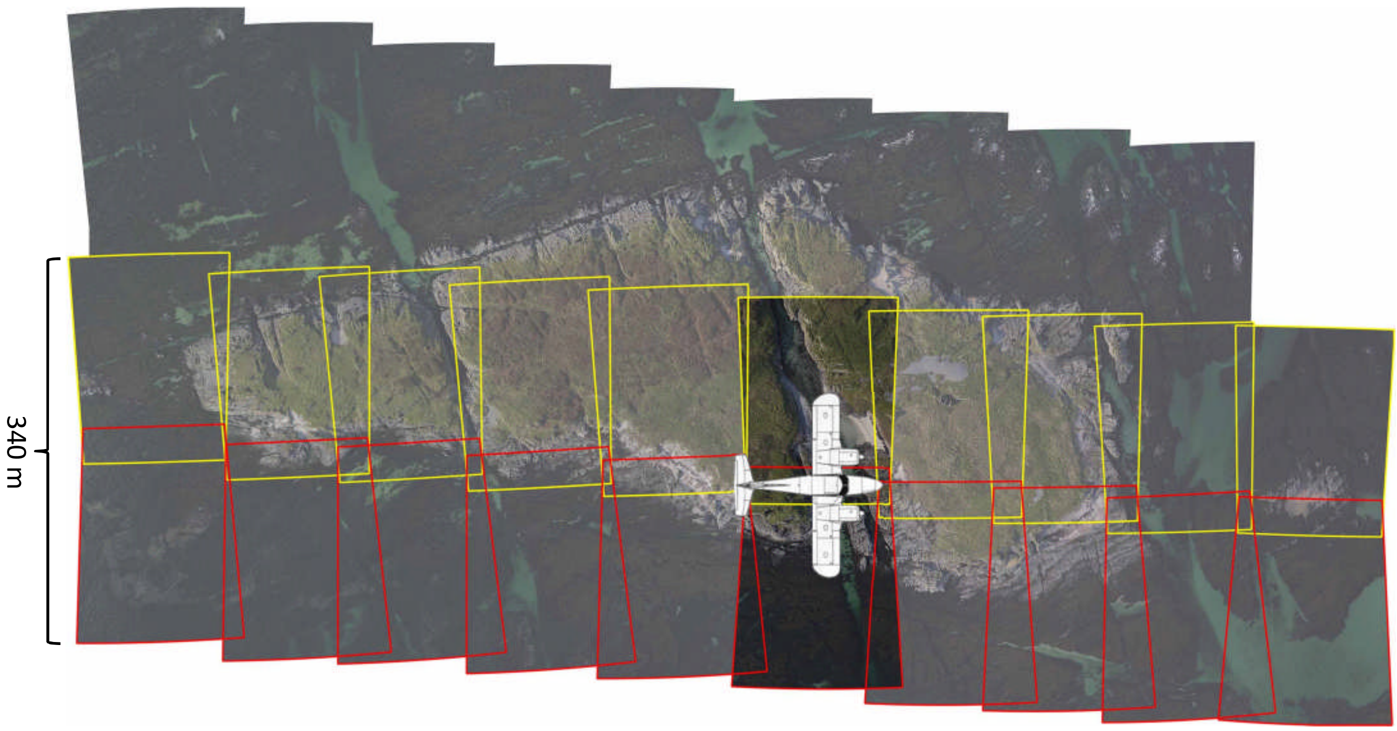


Figure 3. The individual footprints of each pair of photographs taken on a run over Eilean nan Ron, off Oronsay in the Inner Hebrides, flying at 1100 ft (red: left-hand camera; yellow: right-hand camera).

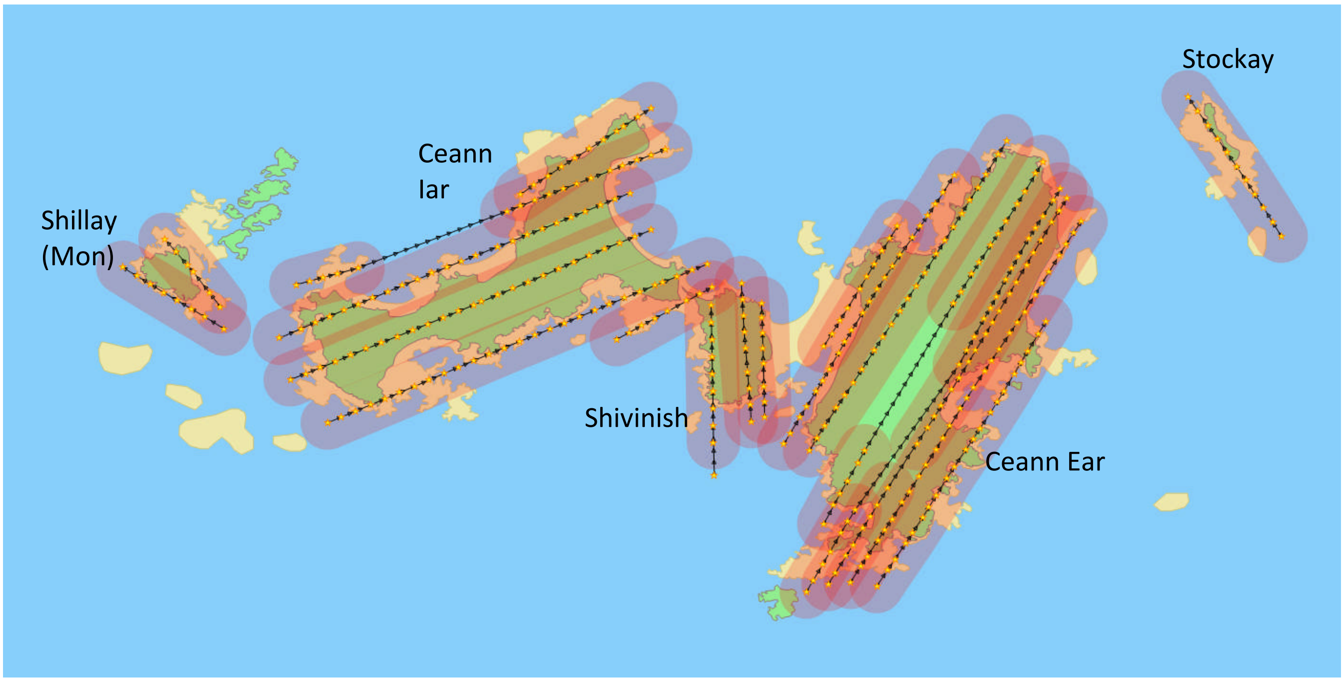


Figure 4. Survey runs and approximate camera trigger locations (yellow dots) for five colonies in the Monach Isles in the Outer Hebrides on 26 October 2012.

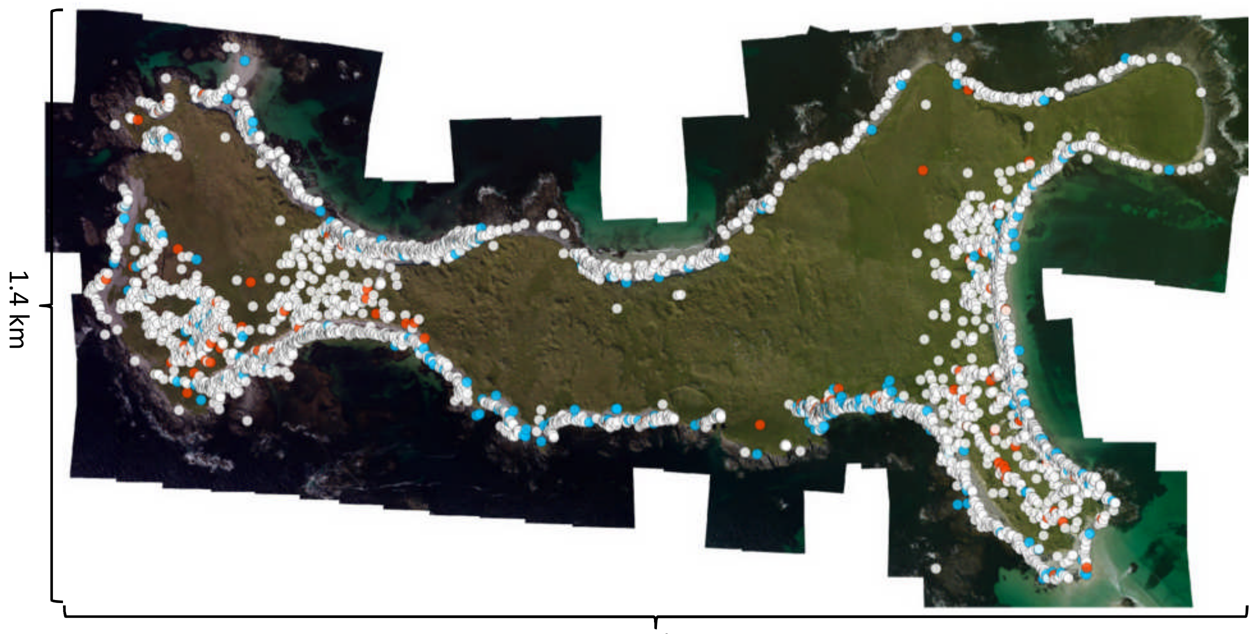


Figure 5. Ceann Iar, the second biggest of the Monach Isles in the Outer Hebrides, is the largest grey seal breeding colony in Europe (ca. 6,000 pups are born each year). This screenshot shows white-coated (white), moulted (blue) and dead pups (red) counted from approximately 200 stitched photographs taken on 7 October 2012. The composite image was stitched together and exported using Microsoft's Image Composite Editor v1.4.4®. The resulting 7.2 gigapixel PSB file (15 GB) was split into 30,000x30,000 pix TIFF tiles using Adobe Photoshop CS5®. These were then imported into Manifold GIS 8.0® for counting.

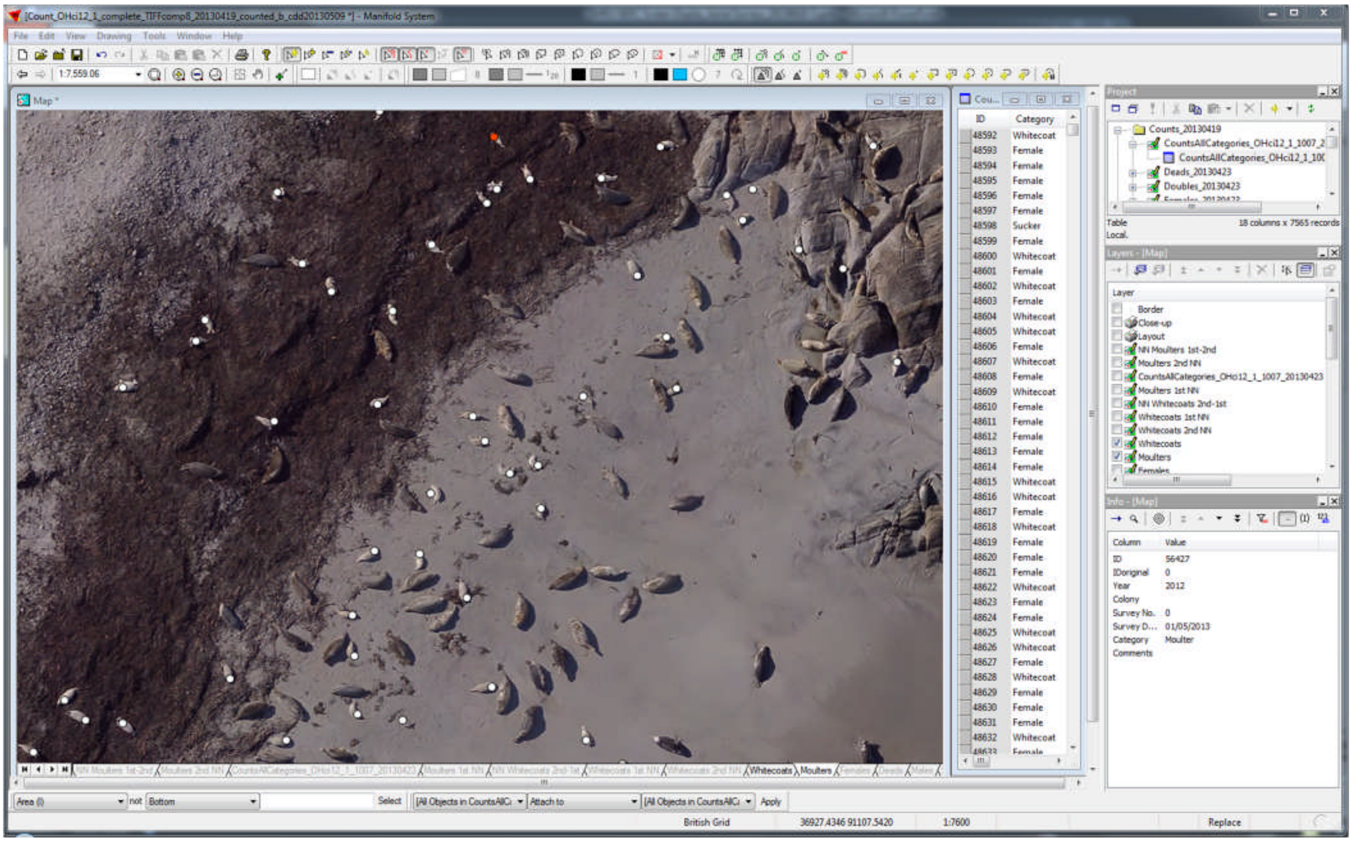


Figure 6. Manifold GIS 8.0® screenshot showing grey seal pups counted on Ceann Iar. Pups of each category (whitecoat, moulted, dead) are counted on a separate layer. The images are not currently geo-referenced but there is the potential for further processing, thus obtaining approximate coordinates for every pup counted.

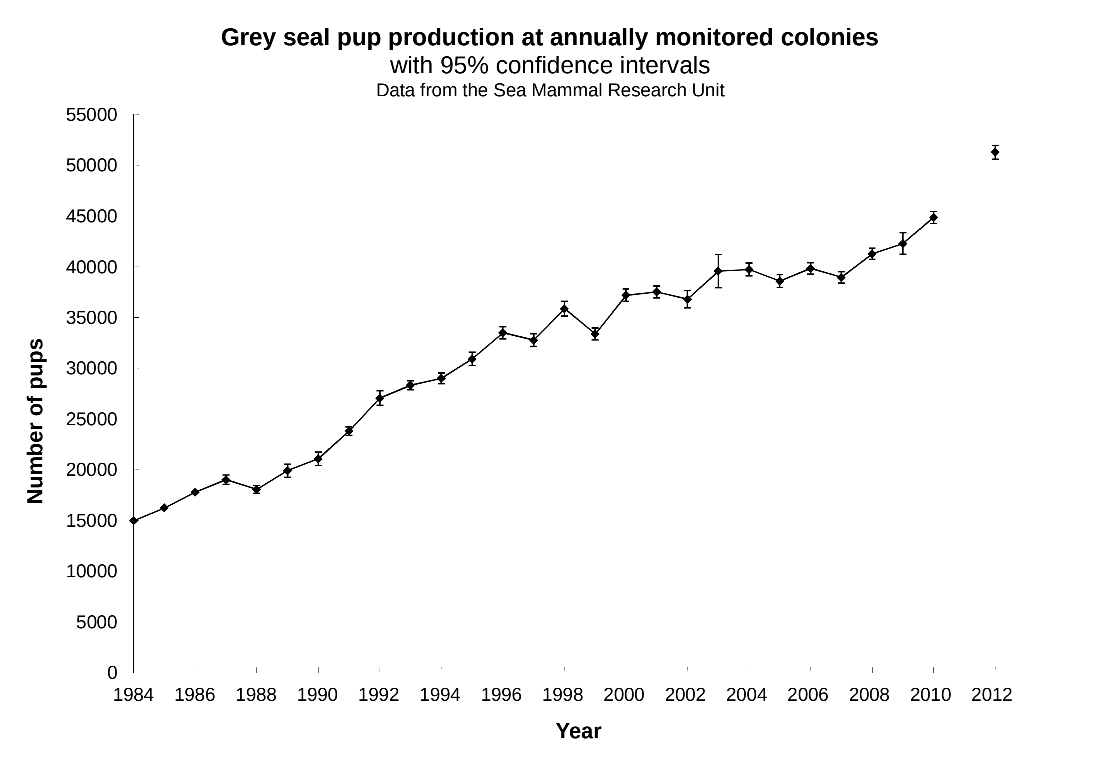


Figure 7. Grey seal pup production at all the major annually monitored colonies in Scotland and England, with 95% confidence intervals from 1984 to 2012.

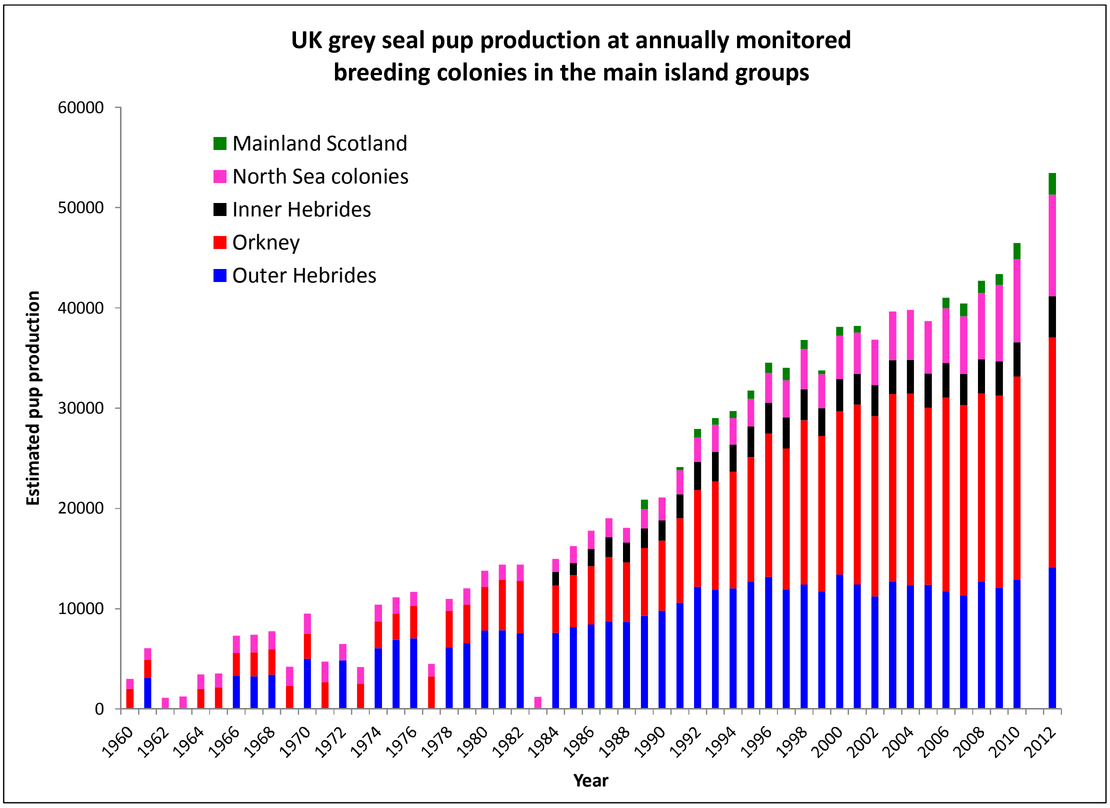
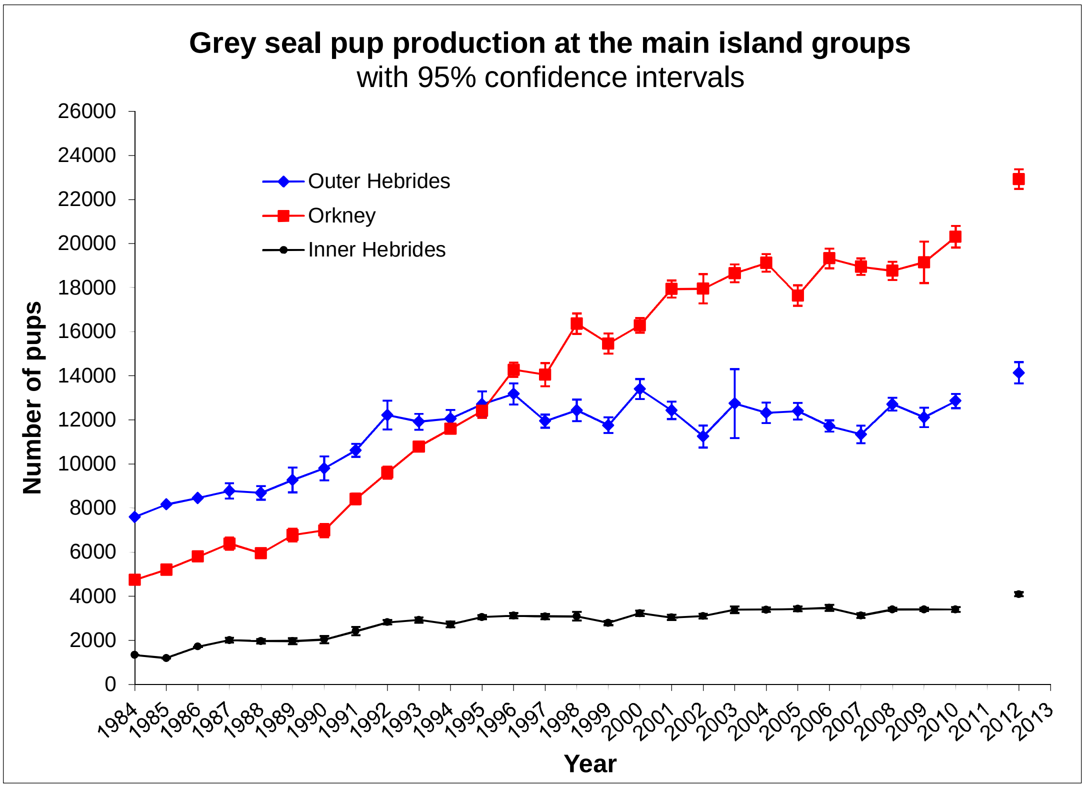


Figure 8. Grey seal pup production at the main 'island' groups between 1960 and 2012.

(a) Outer Hebrides, Orkney and Inner Hebrides (grouped)



(b) North Sea Colonies (individually)

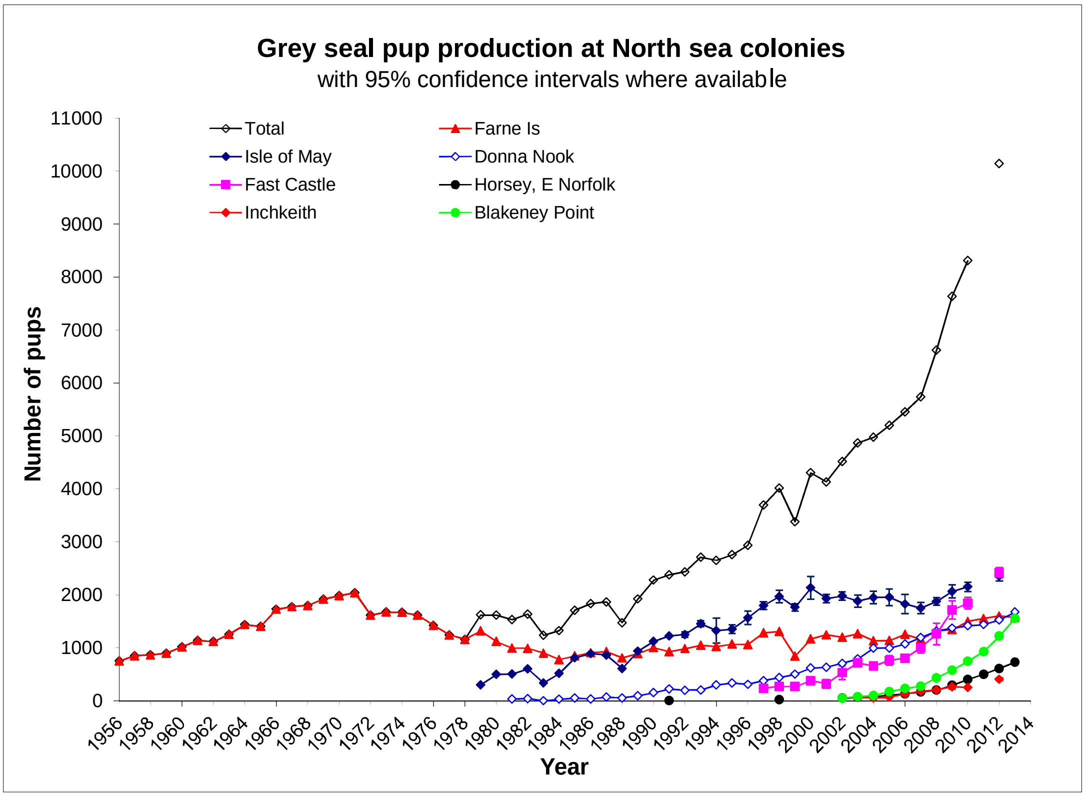


Figure 9. Trends in pup production at the main grey seal breeding colonies since 1984. Production values are shown with 95% confidence intervals where available.

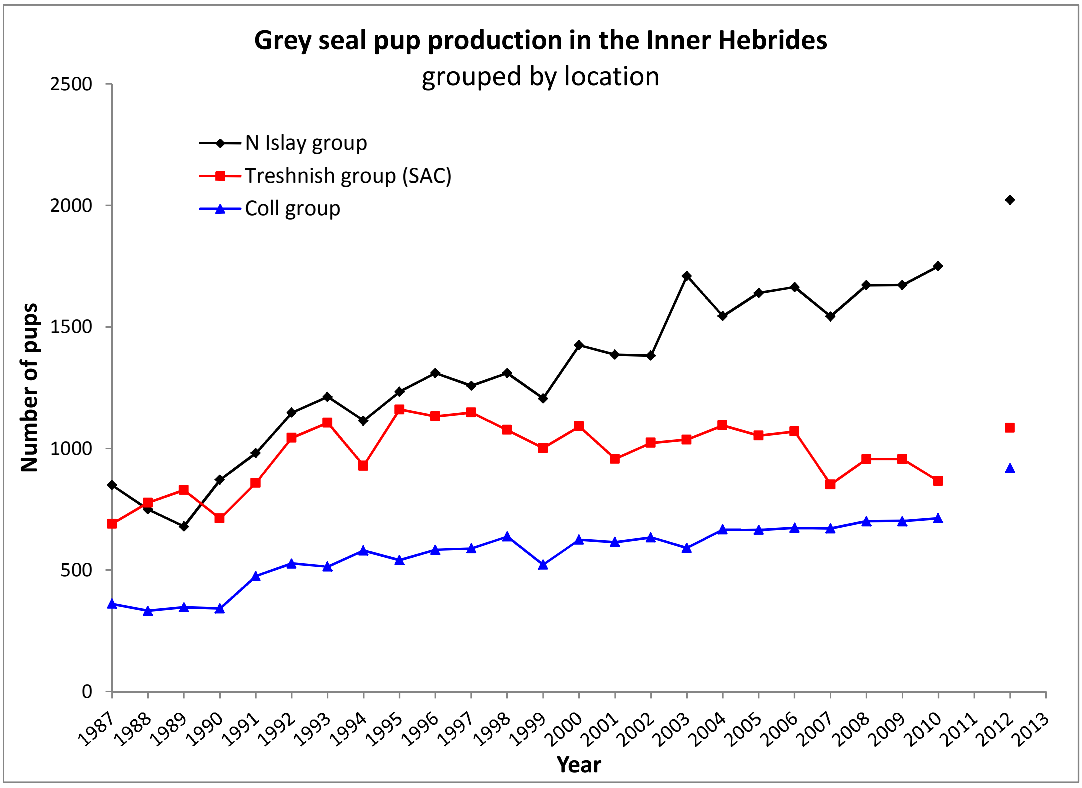


Figure 10. Grey seal pup production at colonies in the Inner Hebrides, grouped by location. Regular surveys of grey seals breeding in the Inner Hebrides only started in the 1980s.

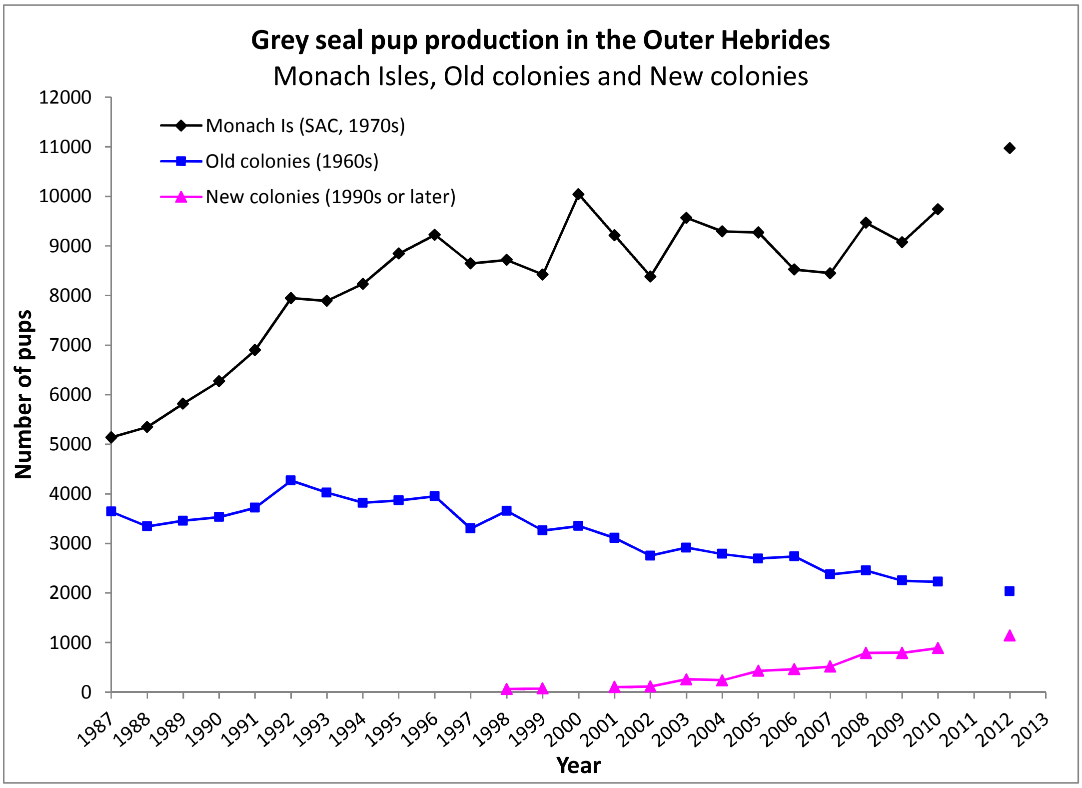


Figure 11. Grey seal pup production in the Outer Hebrides, comparing the Monach Isles, old colonies and newly established colonies.

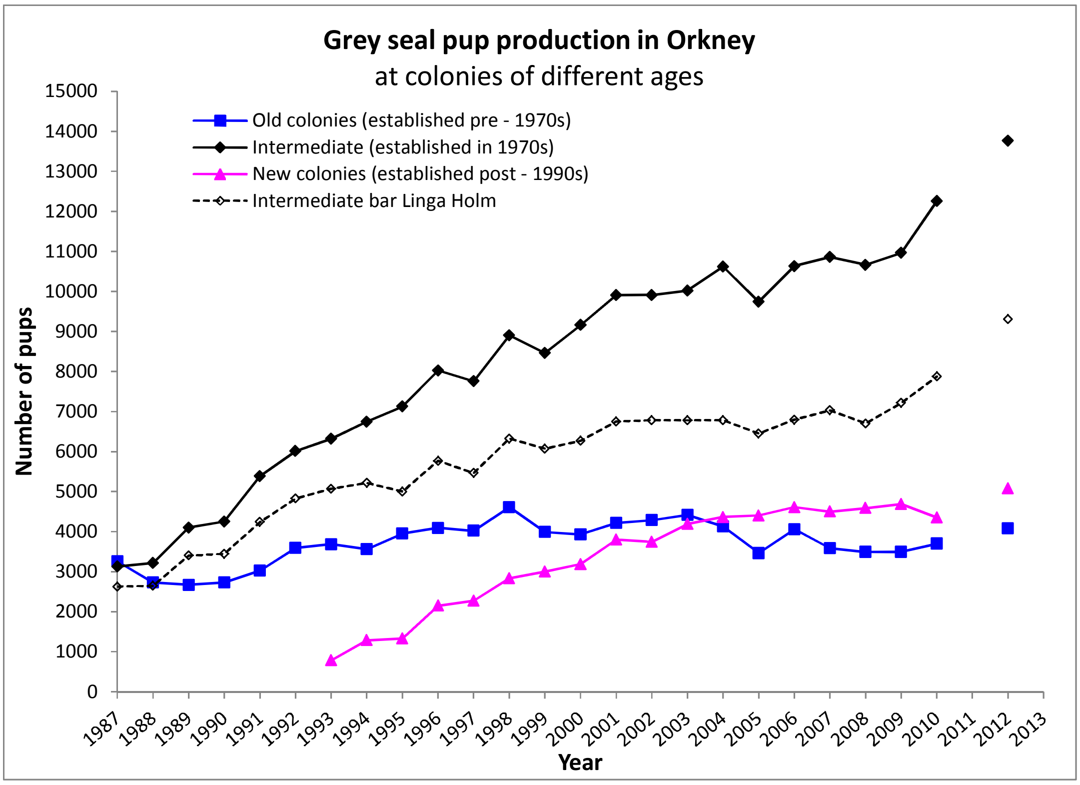


Figure 12. Grey seal pup production at colonies in Orkney, comparing colonies well established before the 1970s (Old), colonies established during the 1970s (Intermediate) and colonies established during and after the 1990s (New).

Appendix

Is there a bias in aerial surveys of grey seals due to the change in technology?

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Introduction

Aerial surveys to estimate grey seal pup production have been conducted using film photography from 1987 to 2010. In 2012, the photographic equipment was upgraded to a digital system. 2012 also corresponded to a noticeable and widespread increase in counts so there was a concern that the increase is due to the change in technology. In order to determine whether the increase is "abnormally" high, changes in counts from 2010 to 2012 (switch to digital) were compared to 2-year changes in counts during previous years because no aerial survey was conducted in 2011.

Data

Counts from four regions of the Scotland from 1987 to 2012 were used for the analysis (Table 1; Figure 1). Counts were log-transformed and changes in log-counts (ΔlogCount) were obtained for 2-year intervals (Figure 2).

Table 1 Number of haul outs per region

Region	Number of haul outs
Orkney	26
Inner Hebrides	10
Outer Hebrides	15
North sea	3
Total	**54**

Method

Two different analyses were used to compare the changes in counts from film vs digital photography.

In the first analysis, a Null distribution of ΔlogCount was generated by resampling years (pre-digital) and haul outs within years in 10 000 bootstrap samples. Each sample consisted of 54 locations in a year, the number of locations for 2012 (digital).

In a second analysis, the mean difference between ΔlogCount for digital and film for all haul outs was calculated. This difference was compared to a Null distribution of differences generated by randomly permutating the treatment (digital vs film) within haul outs (10 000 iterations).

Analyses were replicated using counts starting 2008, 2000 and 1989 (all data available).

Figure 1. Grey seal pup counts by haul out in four different regions (starting 2000). Lines are time-series of haul out counts at 2-year intervals. Red indicates the transition from film to digital photography.

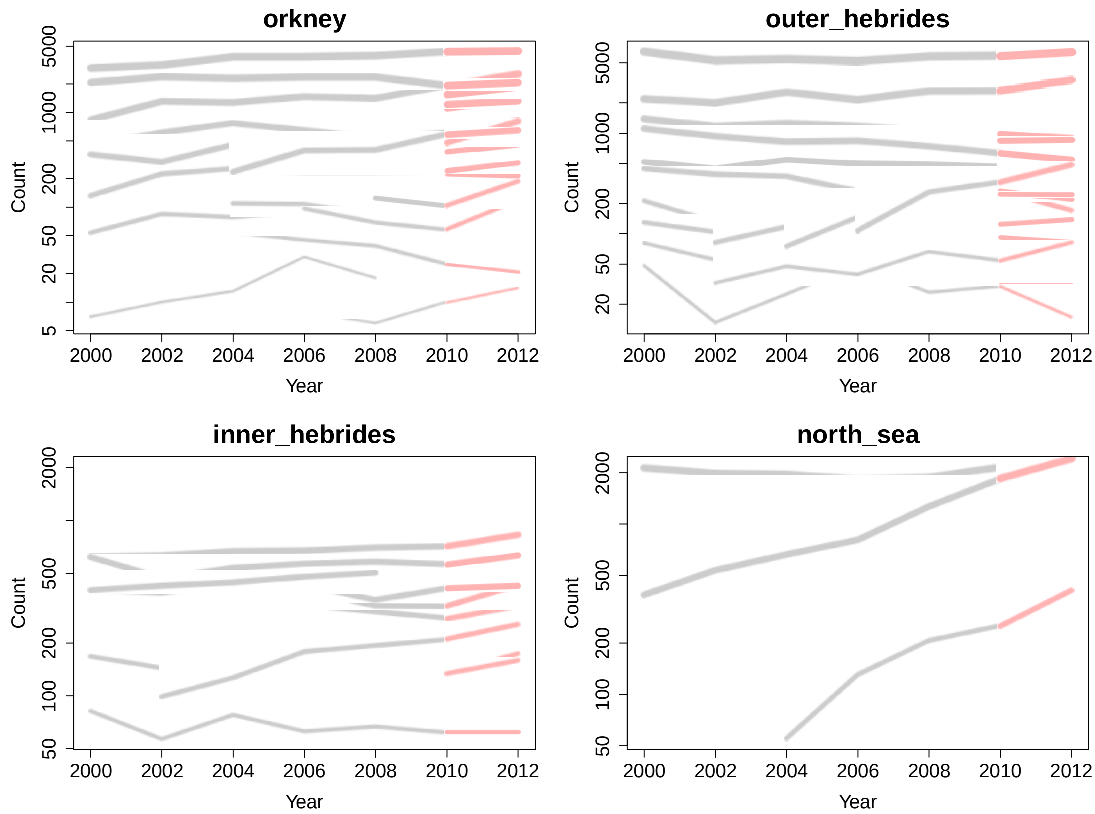


Figure 2. Distribution of ΔlogCount by year (all haul outs). The last boxplot (red) is for the transition to digital photography.

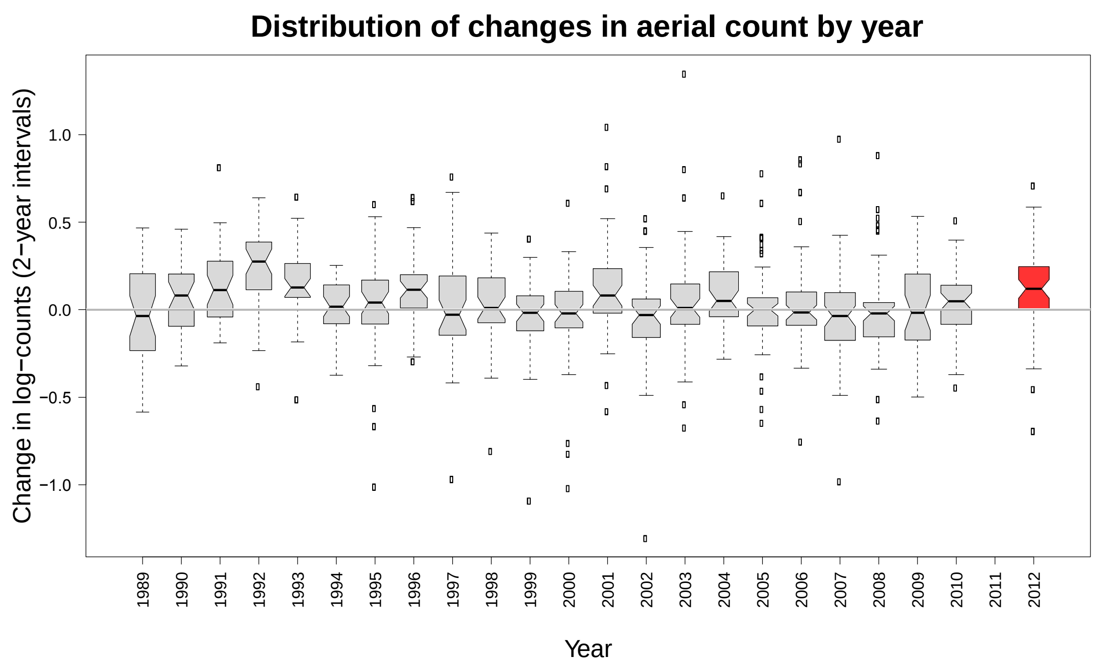
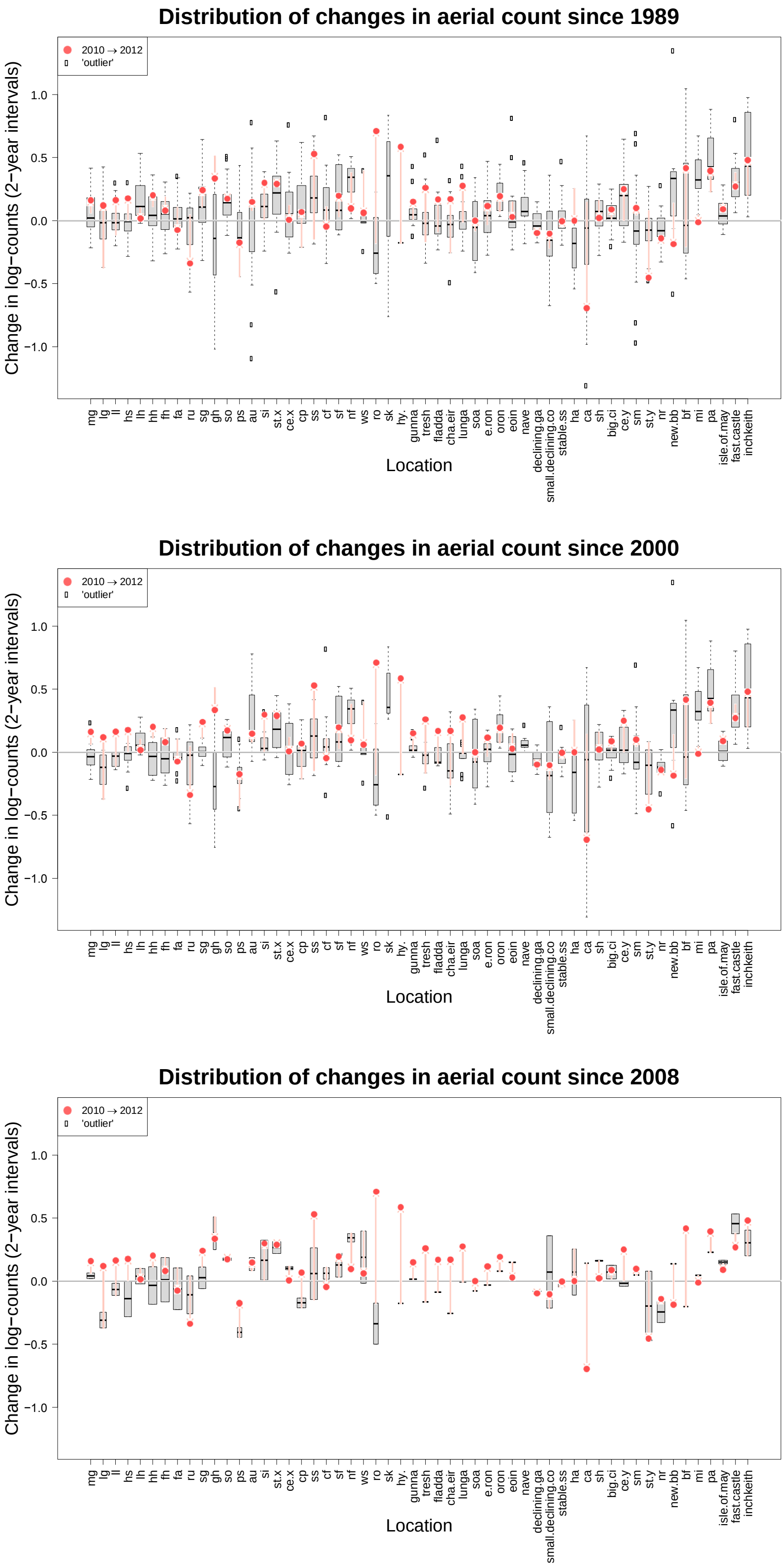


Figure 2. Boxplots of ΔlogCount by haulouts for surveys based on film (starting a. 1989, b. 2000, c. 2008). The red dots show the ΔlogCount for 2012 (digital) and arrows show the change from 2010 (last film count) to 2012.

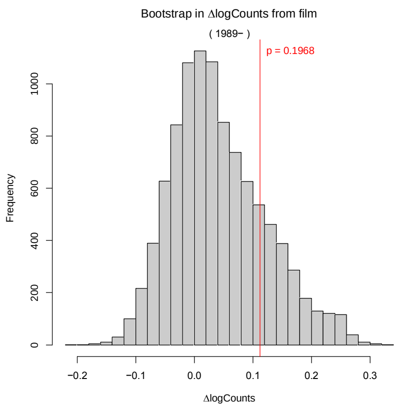


Results

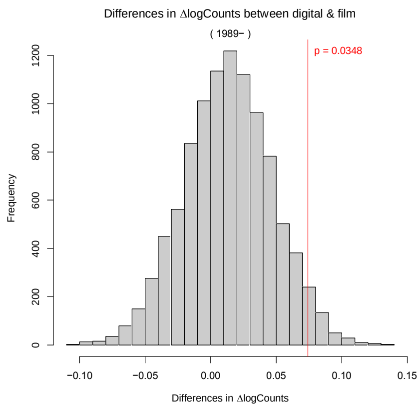
The mean ΔlogCount of 0.112 for 2012 (digital) was significantly different than the null mean only when excluding earlier counts (Figure 3a-c). The mean difference in ΔlogCounts between digital and film was significantly different from the null distribution (Figure 3d-f). The mean difference was greater when excluding early years (from 1989: 0.074; 2000: 0.094; 2008: 0.101).

Figure 3. Null distribution of mean ΔlogCount for 10 000 bootstrap samples (a-c) and Null distribution of mean difference between ΔlogCounts of digital and film (d-f). The observed values are shown in red (line) with the associated p-value. Results for subsets of data are by row: all data (a&d), 2000- (b&e), 2008- (c&f).

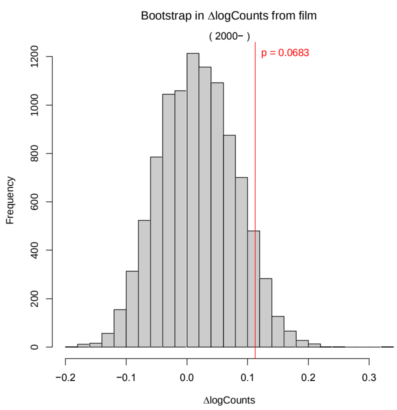
a)



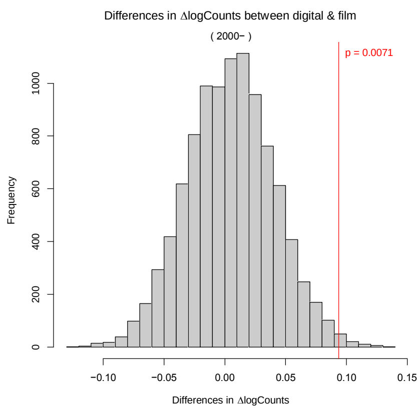
d)



b)

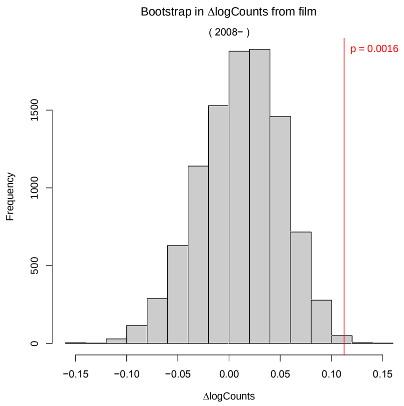


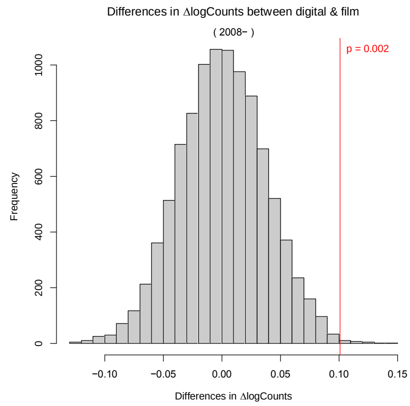
e)



c)

f)





Conclusion

The results were sensitive to the data included in the analyses. Older data contains higher increases in counts (ΔlogCounts) so using the entire record as a reference makes the ΔlogCounts in 2012 (digital) less extreme.

The analysis using permutations suggests a difference in ΔlogCounts of 0.1 in the "worst case scenario", which is equivalent to an increase of approximately 10% in grey seal pup counts. The analysis is based on a single year of data for digital counts. With additional years of data, a more robust comparison will be possible. More complex analyses could be used. For example, a trend line could be fitted to the change in counts using film counts only and make projections for 2012.

The results suggest that the increase in counts from 2010 to 2012 is atypically high considering the previous records. The increase could be due to the change in technology but could equally be to a real increase in grey seal pup numbers.

Estimating the size of the UK grey seal population between 1984 and 2013, using established and draft revised priors

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Abstract

We fitted a Bayesian state-space model of British grey seal population dynamics to two sources of data: (1) regional estimates of pup production from 1984 to 2012, and (2) an independent estimate assumed to be of total population size just before the 2008 breeding season. The model allowed for density dependence in pup survival, using a flexible form for the density dependence function, and assumed no movement of recruiting females between regions. This model is identical to the EDDSNM model used in previous briefing papers, and used the same priors on demographic parameters that have been used since 2005. We used the model to predict past the last data point (2012) to give estimates of population size in 2013. Estimated adult population size in 2013 was 106,300 (95% CI 86,100-131,300).

In addition, we fitted the model using a set of revised priors on demographic parameters that were introduced in a 2012 briefing paper, but with a new prior on adult sex ratio that assumes the ratio of adult males to females is 90% certain to be between 0.68:1 and 0.73:1. Using these revised priors, estimated adult population size in 2013 was 98,800 (95% CI 81,400-122,000).

Introduction

This paper presents estimates of British grey seal population size and related demographic parameters, using identical models and fitting methods to Thomas (2013, and previous years), but including pup production estimates for 2012 and projecting forward one more year to estimate population size in 2013. Models are specified using a Bayesian state space framework with informative priors on demographic parameters, and fitted using a Monte Carlo particle filter. In past briefing papers, multiple models of the population dynamics have been fitted and compared, representing differing hypotheses about the demographic parameter subject to density dependent regulation. The model where density dependence affects pup survival was found to be better supported by the data than one where density dependence affects female fecundity; hence only the former is used here.

Some additional investigations are also undertaken, related to the priors used on demographic parameters. Lonergan (2012) introduced a revised set of priors, based on updated information and discussions within the Sea Mammal Research Unit; these were used by Thomas (2012, 2013) to assess what difference these make to the population estimates and this study is repeated here. We also investigate the consequences of using a newly-derived prior on sex ratio, rather than assuming a fixed sex ratio, as in previous analyses. Thomas (2013) investigated the use of use of separate regional models, rather than the current global model, and also the effect of using priors on fecundity that are derived directly from the intensive studies on Isle of May and North Rona; we do not repeat this work in the current paper.

Materials and Methods

Process model

The population dynamics model is described fully in Thomas and Harwood (2008) and papers cited therein (it is referred to there as the EDDSNM model). In summary, the model tracks seal population numbers in 7 age groups (pups, age 1-5 females, which do not pup, and age 6+ females, which may produce a single pup) in each of four regions (North Sea, Inner Hebrides, Outer Hebrides and Orkney). There are three population sub-processes: (1) survival, (2) ageing and pup sexing and (3) breeding. (The models of Thomas and Harwood 2008 also included movement of age 5 females between regions, but we assume no movement in the current model.) The model has 8 parameters: adult (i.e., age 1 and older) female survival, ϕ_a, maximum pup survival, $\phi_{j\max}$, one carrying capacity parameter-related parameter for each region, β_1 - β_4, a parameter, ρ, that dictates the shape of the density-dependent response and fecundity (i.e., probability that an age 6+ female will birth a pup), α.

The model does not describe the dynamics of adult male seals. To obtain an estimate of total population size we followed previous briefing papers in multiplying the female population size by a fixed value of 1.73, i.e., assuming that females make up 57.8% of the adult population. However, Lonergan (2012) provided a prior for this multiplier, and this was further discussed by Thompson (2014). We therefore also obtained results using a prior based on Thompson (2014), as detailed below under Additional investigations.

Data, observation models, and priors

One source of input data was the pup production estimates for 1984-2010 and 2012 from Duck (2014), aggregated into regions. Note that the North Sea totals included the Inch Keith colony, which had not been included in previous models – this made the North Sea totals approximately 3% greater than previously (e.g., 252 pups added to 8062 in 2012).

The pup production estimates were assumed to be normally distributed with mean equal to the true pup production in each region and year, and constant coefficient of variation (CV). We followed previous papers (e.g., Thomas 2011) in undertaking an initial run of the model with the CV as a parameter to be estimated, and then fixing the value at the posterior mean in subsequent runs. The prior distribution used was gamma(shape=2.1, scale=66.67) on $1/CV^2$, which implies a prior mean CV of 10.4%, with prior 2.5th and 97.5th quantiles of 5.1% and 23.3%, respectively.

The second source of input data was a single estimate of adult population size of 88,300 (95% CI 75,400-105,700) obtained by Lonergan et al. (2010) from summer haulout counts and telemetry data. We followed previous briefing papers (e.g., Thomas 2012) in assuming the estimate was of population size just before the start of the 2008 breeding season, and by representing the uncertainty in the estimate (which Lonergan obtained via a nonparametric bootstrap) using a right-shifted gamma distribution.

Prior distributions for the process model parameters were the same as those used in previous briefing papers (first introduced in Thomas and Harwood 2005), and are given in Table 1. (We also did runs using alternative priors – see Additional investigations, below.) We followed Thomas and Harwood (2005) in using a re-parameterization of the model to set priors on the numbers of pups at carrying capacity in each region, denoted χ_r for region r, rather than directly on the βs. Prior distributions for the states were generated using the 1984 data, as described by Thomas and Harwood (2008).

In summary, the data and priors used here are almost identical to those used by Thomas (2011) and subsequent papers; the only differences are that there is an additional year of pup production data (from 2012), the Inch Keith colony was included in the North Sea region and the observation error parameter has been re-estimated.

Fitting method

We used the particle filtering algorithm of Thomas and Harwood (2008). This involves simulating samples ("particles") from the prior distributions, projecting them forward in time according to the population model, and then resampling and/or reweighting them (i.e., "filtering") according to their likelihood given the data. An identical algorithm to that of Thomas and Harwood (2008) was used for the pup count data, and the additional adult data was included by reweighting the final output according to the likelihood of the estimated 2008 population size, as described by Thomas (2010).

The final output is a weighted sample from the posterior distribution. Many samples are required for accurate estimation of the posterior, and we generated 1,000 replicate runs of 1,000,000 samples. A technique called rejection control was used to reduce the number of samples from the posterior that were required to be stored, and the effective sample size of unique initial samples was calculated to assess the level of Monte Carlo error, as detailed in Thomas and Harwood (2008). (The rejection control threshold used was w_c=1000, which is rather higher than that used in previous years. Initial investigations found that this had little effect on the Monte Carlo error in results, while greatly reducing the size of the posterior sample and hence making the outputs easier to work with on the computer.)

Additional investigations

Revised priors

We re-fitted the model using the revised priors suggested by Lonergan (2012; see Table 1). Here, 2,000 replicate runs of 1,000,000 samples were used.

Prior on sex ratio

In calculating total population size, the above models assume a fixed multiplier of 1.73 on the estimated adult female population. However, given the independent estimate of total population size, it is possible to estimate the multiplier value, given a prior distribution. We implemented this by developing a prior based on the discussion by Thompson (2014) such that 90% of the prior mass was between 1.68 and 1.73 – the distribution (denoted ω in Table 1) had a prior mean of 1.70 and standard deviation of 0.020. (In practice, including the prior in the analysis involved re-weighting the outputs from the previous revised priors analysis, so no additional model runs were required.) Note that this prior is narrow, with a 90% prior interval of 0.05, and also close to the previous fixed value of 1.73 – hence we do not expect a large change in results from using this prior rather than the fixed value.

Results

Observation CV

The posterior mean estimate of $1/CV^2$ was 91.1 (SD 19.1), which corresponds with a CV of 10.5%. This value was used in all subsequent analyses. Note that this is very close to the value of 9.8% estimated by Thomas (2011) and used in Thomas (2012) and Thomas (2013), which was based on the 1984-2010 pup production data (i.e., without the 2012 data point).

Monte Carlo accuracy

The effective sample size (ESS) of unique particles is a useful measure of the accuracy of the simulation. The ESS based on pup production data alone was 213.4 (Table 2), and after inclusion of the independent population estimate was 21.2. ESSs this small have been shown in previous briefing papers to produce population and parameter estimates accurate to around 2-3 significant figures, so we should expect the estimates reported here to be accurate to at least this level. However, more runs of the model used for final inference may be prudent.

Parameter and population estimates

Model fits to the pup production estimates are shown in Figure 1. In all four regions (except perhaps Orkney), the estimated pup production fails to fit the most recent pup production – this pup production is significantly higher than any previous recorded value, and in Inner and Outer Hebrides is very different from the recent trajectory . The model in general provides a poor fit to some of the observed historical pup productions: in North Sea, it fails to capture the rapid acceleration in pup production from 2008 onwards and hence over-predicts pup production from 2001-2008, while under-predicting the most recent value; in Inner Hebrides, the most recent high pup production estimate has pulled the estimated trajectory upwards, so that all of the previous 13 pup production estimates are below the fitted line; in Outer Hebrides the fitted line misses the very rapid increase in pup production in the early 1990s and sudden levelling off around 1994; in Orkney the fitted line under-predicts pup production from 1994-2004 and then over-predicts all subsequent years until 2012. At least some of this lack of fit can be attributed to the most recent pup production estimates, which "pull" the estimated trajectory away from the data points from previous years (cf. the lines in Figure 1 with those in Figure 1 of Thomas 2013, which did not include the 2012 pup production estimate).

Estimated pup production is very similar with or without the addition of the independent population size estimate (cf. blue and red lines in Figure 1).

Parameter estimates are shown in Figure 2 and summarized in Table 1. The independent population size estimate causes the estimates of adult survival to increase slightly (to 0.96), maximum juvenile survival to decrease (to 0.42), and fecundity to increase slightly (to 0.97) but stay very close to the prior distribution. Comparing the parameter estimates to those obtained without the 2012 pup production estimate (Table 1 and Figure 2 of Thomas 2013), we see that estimates of survival and fecundity are very similar, but that the estimates of carrying capacity in each region are higher, particularly for the North Sea region.

Adult population size estimates are shown in Figure 3; the values for 2013 are also given in Table 3. The independent estimate for 2008 of 88,300 (with 95%CI 75,400-105,700) is lower than the value predicted for that year from pup production data alone (130,300, with 95% CI 101,700-162,500), although the credible/confidence intervals just overlap. When the independent estimate is included in the population dynamics model fitting, the estimate for 2008 from this model decreases by 22% to 101,600 (95%CI 85,800-121,700). Estimates for all years from the model fit to both pup production data and the independent estimate are given in Appendix 1. The estimates for recent years are approximately 5% greater than those for the same years given in Thomas (2013), i.e., those without the most recent pup production estimates.

Additional investigations

Revised priors
As might be expected (and as was shown in previous briefing papers), use of revised priors caused differences in posterior parameter estimates (Figure 4 and Table 1). Adult survival was estimated to be higher, and maximum pup survival lower; fecundity was estimated to be higher but was, just as with the previous analysis, almost completely governed by the prior distribution. Addition of the 2008 independent population estimate caused the estimate of adult survival to increase still further (to an implausible 0.99) and maximum pup survival to decrease further (to an also unlikely 0.27), while fecundity was also slightly higher.

Estimates of total population size are slightly lower without the independent population estimate (cf. blue lines on Figure 3 and 5; see also Table 4), which is unsurprising given the revised prior (and posterior) on fecundity is lower; the credible interval is also wider. The addition of the independent population size estimate again lowers the total population size estimate, and the result is somewhat lower than with the old priors (cf. red lines on Figures 3 and 5).

Prior on sex ratio
As expected, the prior on sex ratio does not change the posterior distributions on model parameters greatly, even with the addition of the 2008 independent population estimate (cf. Figures 6 and 4; Table 1). This is because the prior on sex ratio is highly informative relative to the information in the data (i.e., the independent population estimate) on sex ratio.

The resulting estimate of total population size was similar to that with the fixed prior on sex ratio – slightly lower because the prior mean on sex ratio was slightly lower than the fixed value (cf. Figures 7 and 5; Table 4). Estimates for all years from the model fit to both pup production data and the independent estimate are given in Appendix 2.

Discussion

Main analysis
The 2012 pup production estimate is 14% higher than the 2010 estimate – an increase of approximately 7% a year. This is greater than the median increase in estimated pup production of approximately 4% per year. This estimate caused the estimated total population size in recent years to be approximately 5% larger than estimates made previously without the 2010 data (e.g., Thomas, 2013). The new pup production estimate also caused the estimated population growth rate to

increase slightly: the estimate from Thomas (2013) for the years 2011-2012 was 0.2%; the new estimate for the same pair of years is 0.9%.

The fitted model does not capture all the features of the pup production data – there are clear runs of positive or negative residuals (Figure 1), and in no region except Orkney does the model fit the last data point (from 2012) well. It may be useful to investigate potential causes of inter-annual variation in fecundity – an initial analysis could be made of the residuals verses potential explanatory variables.

Additional investigations

Thomas (2013) made an initial investigation of the sensitivity of the total population size estimate to changes in priors on demographic parameters. He found that changing priors on adult or pup survival had little effect on estimated total population size because of a strong inverse correlation between the two parameters; by contrast, changing the prior on fecundity had a strong effect since it was highly informative (in the sense that the posterior was almost identical to the prior) and not correlated with the other parameters. Hence it seems likely that the changes in population size observed with use of the revised priors is caused by the revised prior on fecundity.

Thomas (2013) also investigated the effect of allowing sex ratio to be a parameter, rather than assuming it to be fixed, but he used a very different prior on sex ratio from the one used here. Thomas (2013) used a prior with a mean of 1.2 and standard deviation of 0.63, based on the suggestion of Longeran (2012). This produced parameter estimates much closer to those obtained without the independent estimate, and a population size estimate also closer to that from the population model alone, although more precise. It is clear that the prior on sex ratio has a very strong effect on the final estimated population size. While the prior suggested by Lonergan (2012) is thought to include implausibly low values (Thompson 2014), we find that using the narrower, higher prior reported here leads to estimates of adult and maximum pup survival that are implausibly high and low, respectively. Clearly, more work is required to refine the prior distributions for population parameters.

Despite this ongoing uncertainty, our current estimates of adult population size in 2013 are not very different using old priors (106,300 with 95%CI 86,100-131,300) and new priors including the prior on sex ratio (98,800 with 95%CI 81,400-122,000).

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Table 1. ***Prior parameter distributions and summary of posterior distribution****. (The two parameters of the gamma distribution specified here are shape and scale respectively.) Posterior summaries are all from analyses that use both 1984-2010 and 2012 pup production estimates, and the 2008 total population estimates.*

	Main analysis			Additional investigations					
	Old priors			Revised priors			Revised priors with sex ratio not fixed		
Parameter	Prior distribution	Prior mean (SD)	Posterior mean (SD)	Prior distribution	Prior mean (SD)	Posterior mean (SD)	Prior distribution	Prior mean (SD)	Posterior mean (SD)
adult survival ϕ_a	Be(22.05,1.15)	0.95 (0.04)	0.96 (0.015)	0.8+0.2*Be(1.6,1.2)	0.91 (0.05)	0.99 (0.01)	same as previous		0.99 (0.01)
pup survival ϕ_j	Be(14.53,6.23)	0.70 (0.10)	0.42 (0.09)	Be(2.87,1.78)	0.62 (0.20)	0.28 (0.05)	same as previous		0.28 (0.06)
fecundity $\alpha_{\max}$	Be(22.05,1.15)	0.95 (0.04)	0.97 (0.03)	0.6+0.4*Be(2,1.5)	0.83 (0.09)	0.91 (0.06)	same as previous		0.90 (0.06)
dens. dep. ρ	Ga(4,2.5)	10 (5)	3.77 (1.36)	same as previous		6.02 (2.38)	same as previous		5.96 (2.36)
NS carrying cap. χ_1	Ga(4,2500)	10000 (5000)	13100 (3390)	same as previous		14500 (5430)	same as previous		14400 (5260)
IH carrying cap. χ_2	Ga(4,1250)	5000 (2500)	3680 (496)	same as previous		3770 (468)	same as previous		3760 (463)
OH carrying cap. χ_3	Ga(4,3750)	15000 (7500)	12500 (791)	same as previous		13100 (1580)	same as previous		13100 (1540)
Ork carrying cap. χ_4	Ga(4,10000)	40000 (20000)	22300 (2800)	same as previous		23300 (3650)	same as previous		23300 (3660)
observation CV ψ	Fixed	0.098 (0)	-	Fixed	0.89 (0)	-	same as previous		-
sex ratio ω	Fixed	1.73 (0)	-	same as previous		-	1.6+Ga(28.08,3.70E-3)	1.7 (0.02)	1.7 (0.02)

Table 2. ***Number of particles simulated (K), number saved after final rejection control step (K*), number of unique ancestral particles (U), effective sample size of unique particles from pup count data alone(ESS_{u1}), and with pup production data and the independent total population estimate (ESS_{u2}).***

Model	K (x10^7)	K^* (x10^6)	U (x10^4)	ESS_{u1}	ESS_{u2}
EDDSNM Old priors	1000	1.41	10.6	213.4	21.2
EDDSNM New priors	2000	3.93	7.17	702.7	121.9
EDDSNM New priors, estimated sex ratio	n/a				138.3

Table 3. **Estimated size, in thousands, of the British grey seal population at the start of the 2013 breeding season, derived from models fit to pup production data from 1984-2012 and the additional total population estimate from 2008, using the old parameter priors. Numbers are posterior means with 95% credible intervals in brackets.**

	Pup production data alone	Pup production data and 2008 population estimate
North Sea	31.3 (21.9 41.1)	24.3 (18.1 32)
Inner Hebrides	9.7 (7.7 12.2)	7.8 (6 9.4)
Outer Hebrides	34.1 (27.5 41.4)	27 (22.1 32.4)
Orkney	63 (46.9 86.7)	47.2 (40 57.4)
Total	138.1 (104.1 181.5)	106.3 (86.1 131.3)

Table 4. **Estimated size, in thousands, of the British grey seal population at the start of the 2013 breeding season, using a variety of parameter priors. Numbers are posterior means with 95% credible intervals in brackets.**

Total	Pup production data alone	Pup production data and 2008 population estimate
Old priors	138.1 (104.1 181.5)	106.3 (86.1 131.3)
Revised priors	135.1 (91.1 192.8)	100.2 (82.2 124.8)
Revised priors with estimated sex ratio	133.1 (89.6 190.2)	98.8 (81.4 122)

Figure 1. Posterior mean estimates of pup production (solid lines) and 95%CI (dashed lines) from the model of grey seal population dynamics, fit to pup production estimates from 1984-2012 (circles) and a total population estimate from 2008, using the old parameter priors. Blue lines show the fit to pop production estimates alone; red lines show the fit to pup production estimates plus the total population estimate.

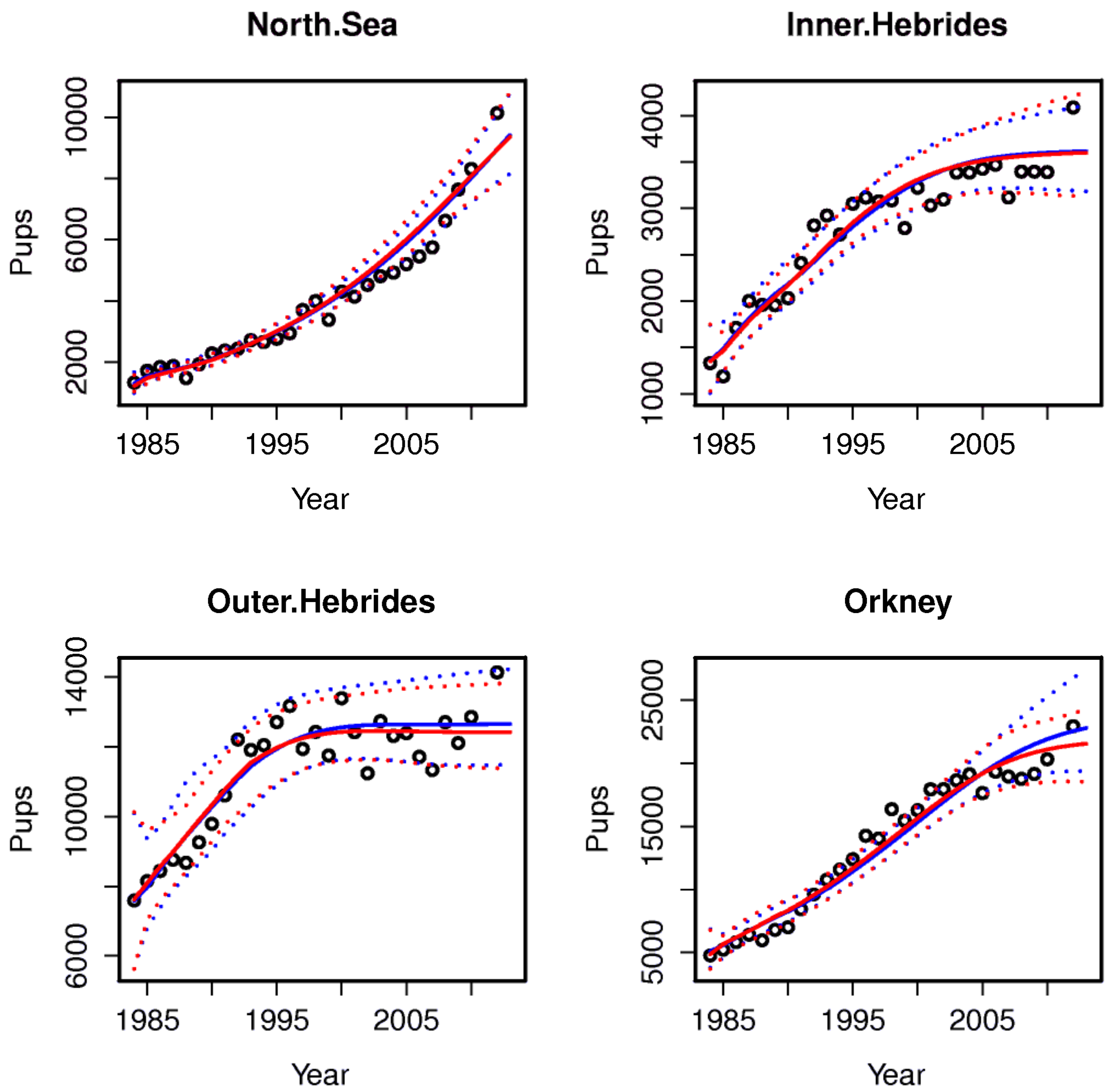
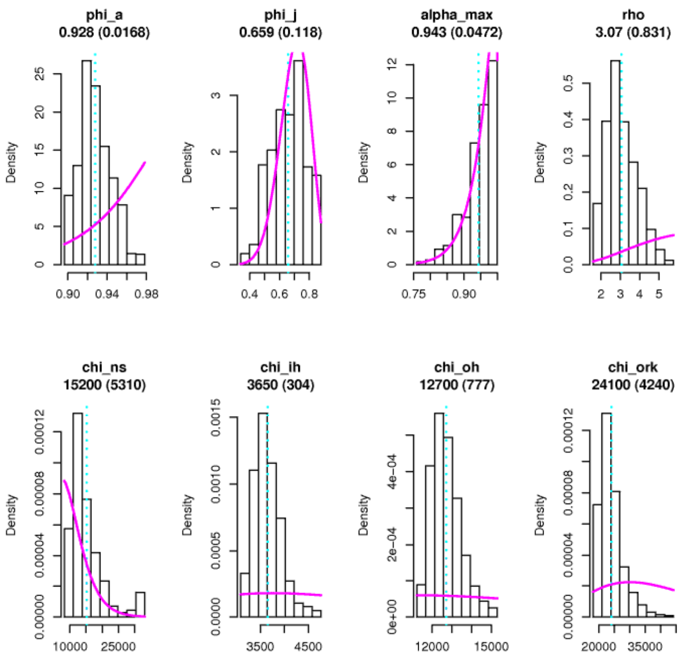


Figure 2. Posterior parameter distributions (histograms) and priors (solid lines) for the model of grey seal population dynamics, fit to pup production estimates from 1984-2012 and a total population estimate from 2008, using the old parameter priors. The vertical line shows the posterior mean; its value is given in the title of each plot after the parameter name, with the associated standard error in parentheses.

(a) Pup production data alone



(b) Pup production data and 2008 population estimate

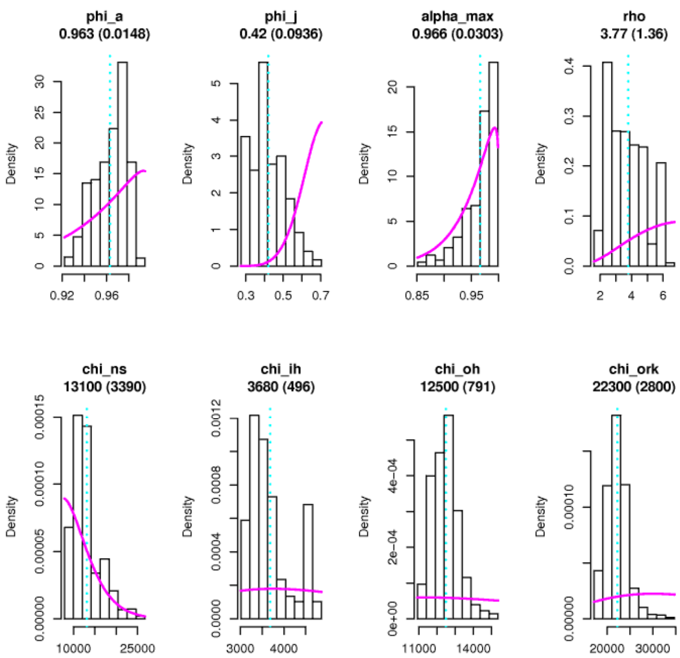


Figure 3. Posterior mean estimates (solid lines) and 95%CI (dashed lines) of total population size in 1984-2013 from the model of grey seal population dynamics, fit to pup production estimates from 1984-2012 and a total population estimate from 2008 (circle, with horizontal lines indicating 95% confidence interval on the estimate), using the old parameter priors. Blue lines show the fit to pop production estimates alone; red lines show the fit to pup production estimates plus the total population estimate.

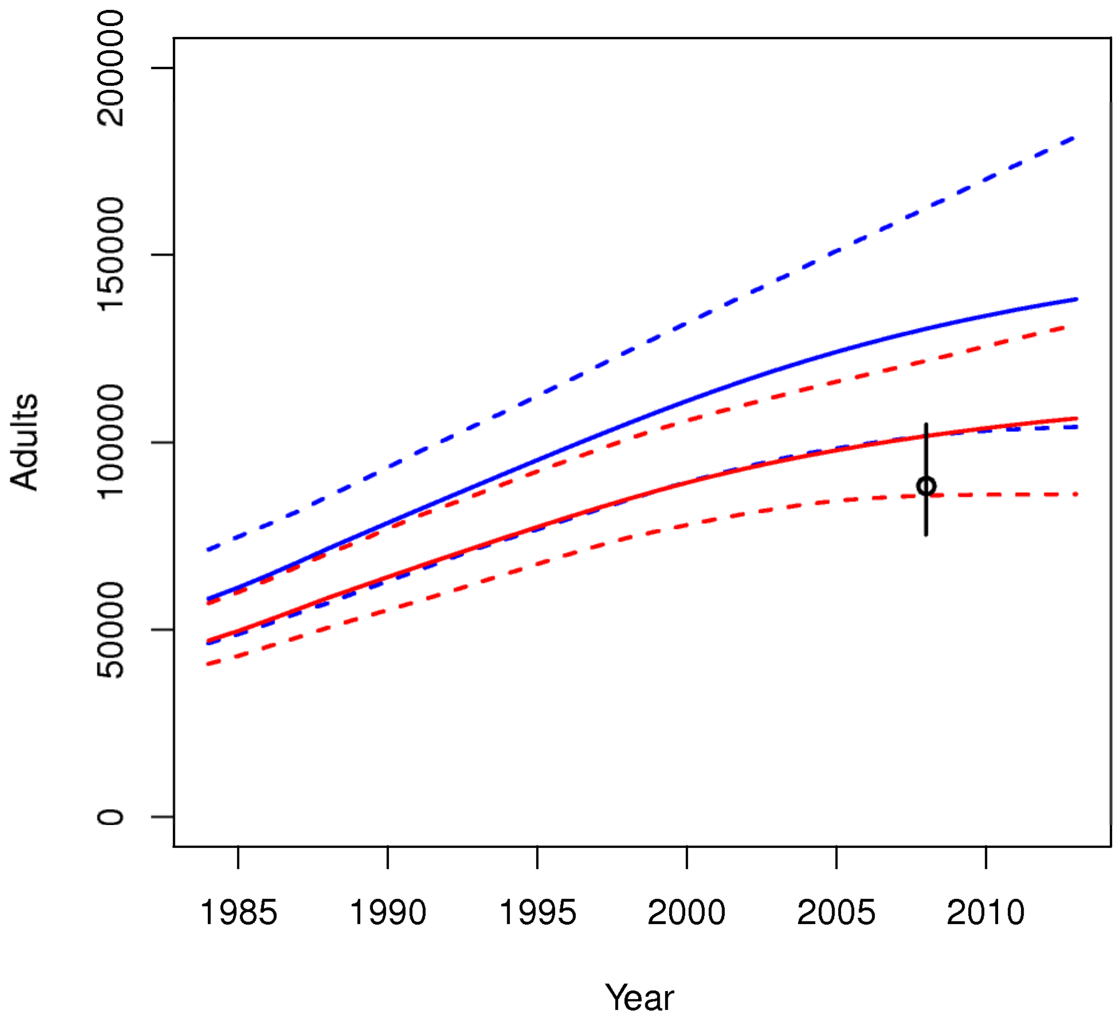
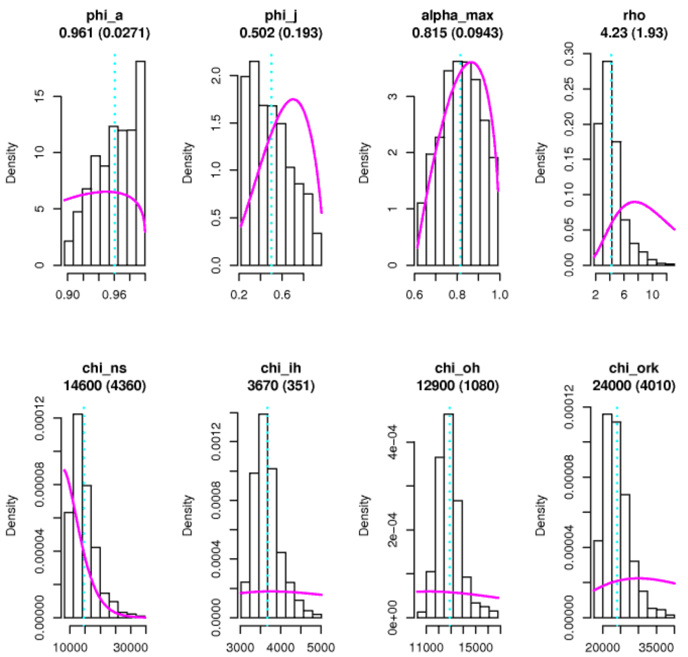


Figure 4. Prior (histograms) and posterior (solid lines) parameter estimates obtained using the revised priors. See Figure 2 legend for further explanation of the plots.

(a) Pup production data alone



(b) Pup production data and 2008 population estimate

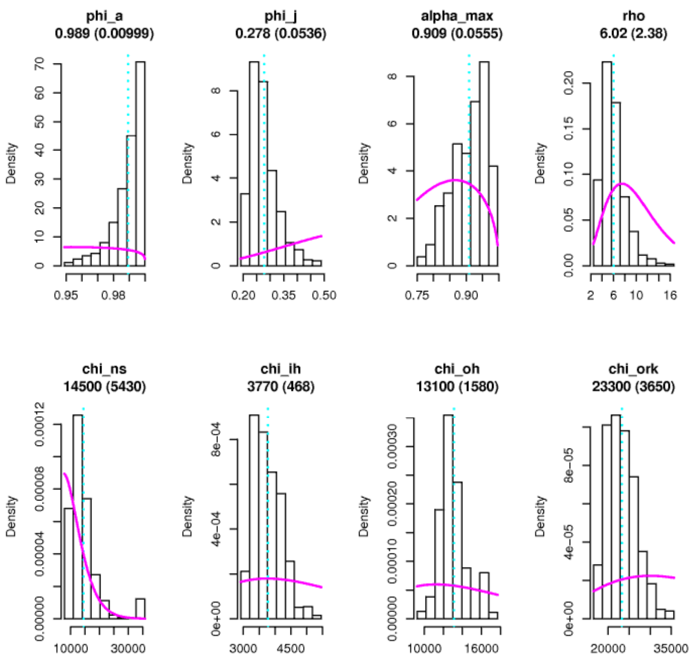


Figure 5. Posterior mean estimates (solid lines) and 95%CI (dashed lines) of total population size obtained using revised priors. See figure 3 legend for further explanation of the plot.

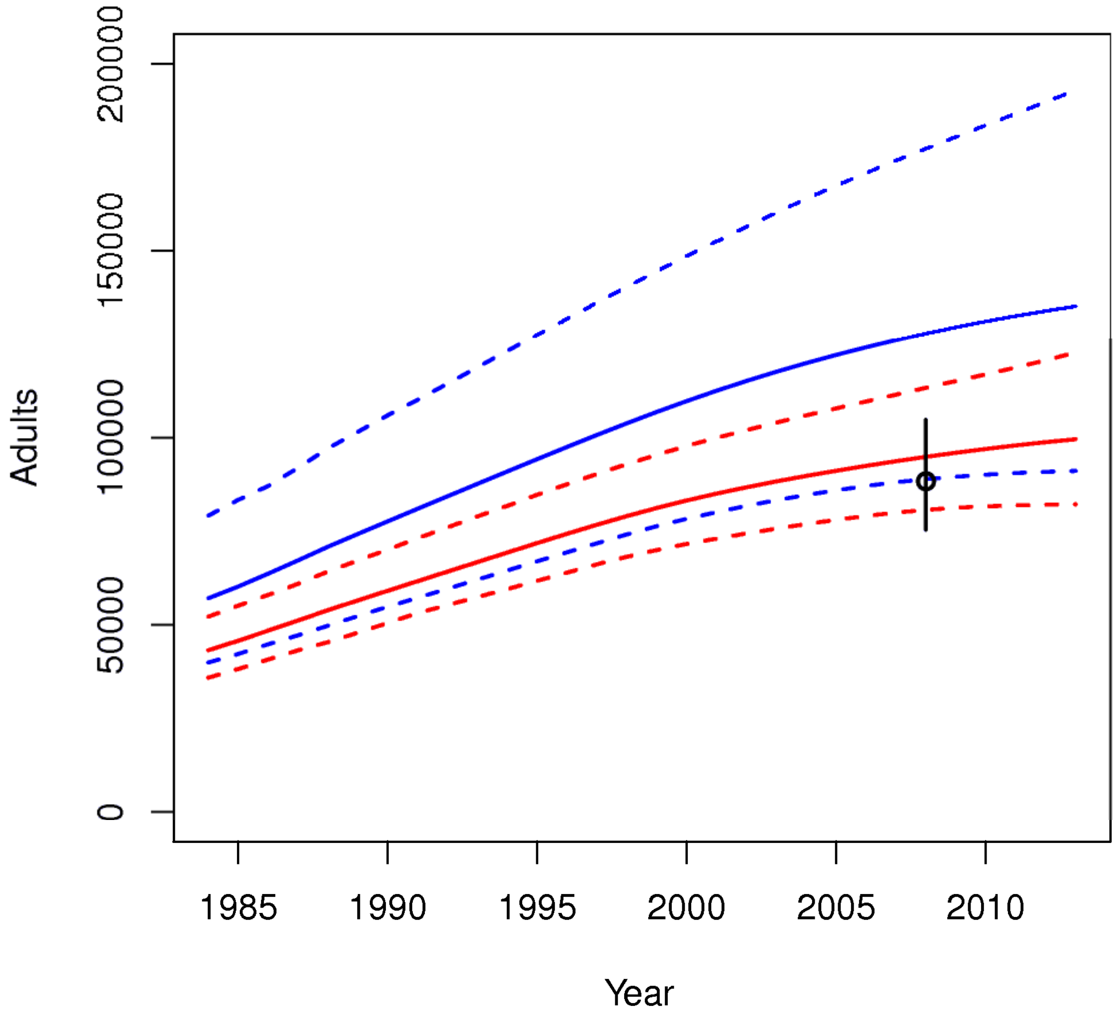
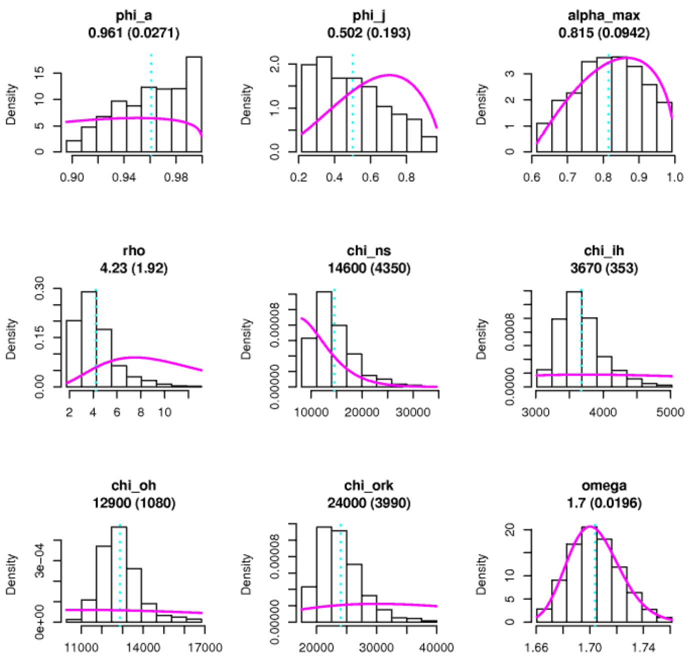


Figure 6. Prior (histograms) and posterior (solid lines) parameter estimates obtained using the revised priors, including a prior on sex ratio. See Figure 2 legend for further explanation of the plots.

(a) Pup production data alone



(b) Pup production data and 2008 population estimate

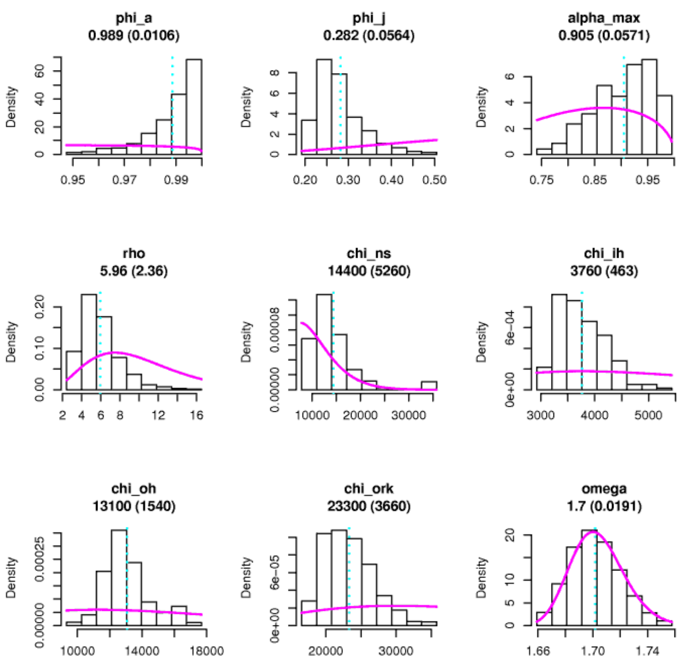
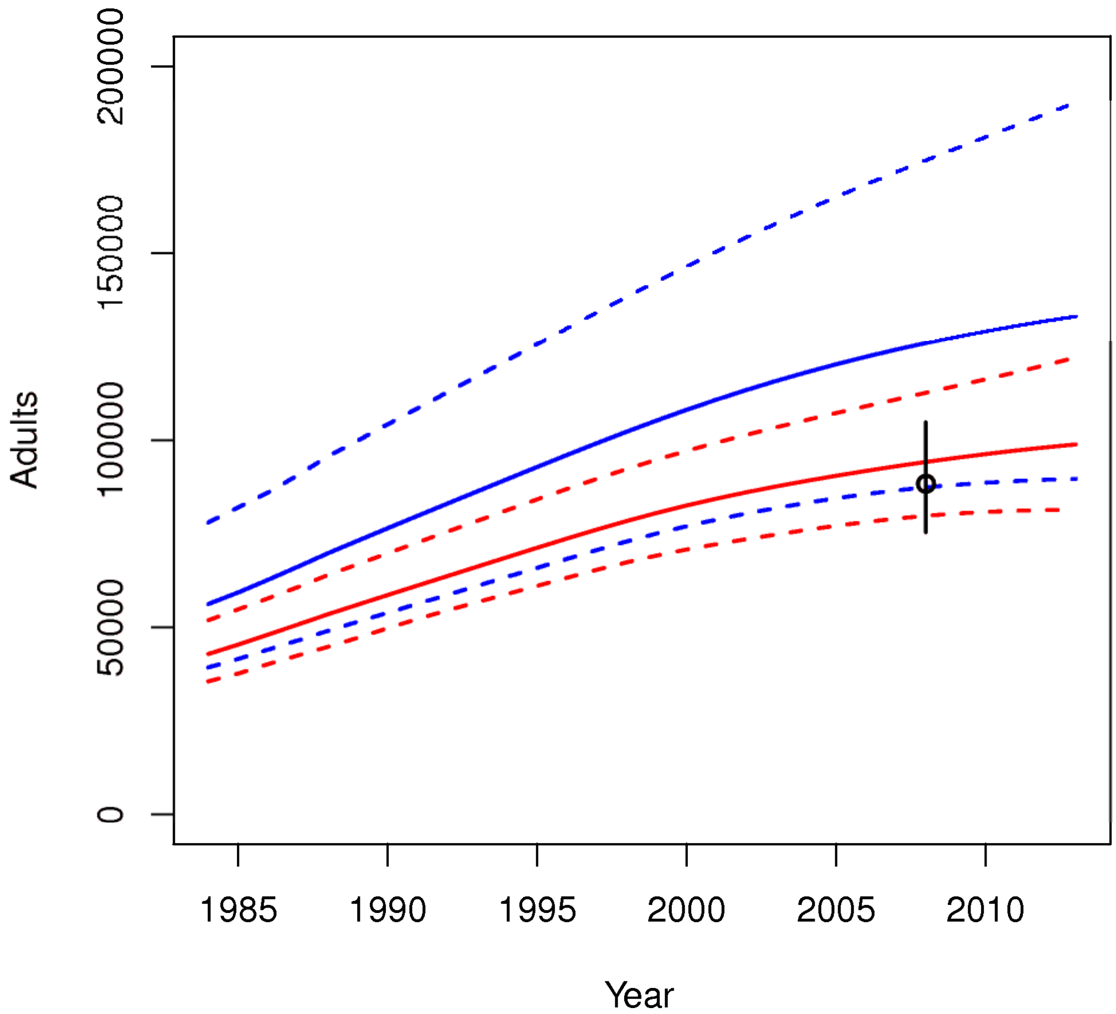


Figure 7. Posterior mean estimates (solid lines) and 95%CI (dashed lines) of total population size obtained using revised priors including a prior on sex ratio. See figure 3 legend for further explanation of the plot.



Appendix 1

Estimates of total population size, in thousands, at the beginning of each breeding season from 1984-2012, made using the model of British grey seal population dynamics fit to pup production estimates and a total population estimate from 2008, and using the old priors. Numbers are posterior means followed by 95% credible intervals in brackets.

Year	North Sea	Inner Hebrides	Outer Hebrides	Orkney	Total
1984	4.2 (3.7 5)	4.5 (3.9 5.5)	21.5 (18.8 26.1)	16.9 (14.5 20.4)	47.1 (40.9 57)
1985	4.5 (4 5.3)	4.7 (4.1 5.8)	22.4 (19.4 27.3)	18 (15.5 21.6)	49.6 (43 60)
1986	4.8 (4.3 5.8)	5 (4.4 6.1)	23.4 (20.2 28.5)	19.3 (16.6 22.9)	52.5 (45.5 63.3)
1987	5.2 (4.6 6.2)	5.3 (4.6 6.5)	24.2 (21 29.6)	20.7 (17.8 24.6)	55.5 (48 66.8)
1988	5.6 (4.9 6.7)	5.6 (5 6.8)	25 (21.5 30.5)	22.2 (19.2 26.3)	58.5 (50.5 70.3)
1989	6.1 (5.3 7.2)	5.9 (5.2 7.1)	25.6 (21.9 30.9)	23.7 (20.6 28.2)	61.3 (52.9 73.4)
1990	6.5 (5.7 7.7)	6.2 (5.4 7.5)	26 (22.1 31.5)	25.3 (22.1 30.2)	64 (55.2 76.9)
1991	7 (6.1 8.3)	6.4 (5.6 7.8)	26.3 (22.3 32.1)	27 (23.6 32.1)	66.8 (57.6 80.3)
1992	7.5 (6.5 8.9)	6.6 (5.8 8.1)	26.6 (22.4 32.3)	28.7 (25.3 33.9)	69.5 (60 83.2)
1993	8.1 (7 9.6)	6.9 (5.9 8.3)	26.8 (22.5 32.4)	30.4 (27 35.9)	72.1 (62.5 86.2)
1994	8.7 (7.5 10.3)	7 (6 8.5)	26.9 (22.6 32.5)	32.2 (28.9 37.9)	74.8 (65 89.2)
1995	9.3 (8 11)	7.2 (6.1 8.7)	27 (22.7 32.5)	33.9 (30.7 40)	77.4 (67.5 92.2)
1996	10 (8.6 11.8)	7.3 (6.1 8.9)	27 (22.7 32.4)	35.6 (32.6 42)	79.9 (70 95.1)
1997	10.7 (9.2 12.7)	7.4 (6.1 9)	27 (22.7 32.3)	37.3 (34.3 43.9)	82.4 (72.3 98)
1998	11.4 (9.9 13.6)	7.5 (6.2 9.1)	27 (22.7 32.3)	38.8 (35.8 45.8)	84.8 (74.5 100.8)
1999	12.2 (10.6 14.5)	7.6 (6.2 9.2)	27 (22.6 32.3)	40.3 (36.9 47.5)	87.1 (76.2 103.4)
2000	13 (11.3 15.5)	7.6 (6.1 9.2)	27 (22.6 32.2)	41.5 (37.8 48.9)	89.2 (77.9 105.8)
2001	13.9 (12.2 16.5)	7.7 (6.1 9.2)	27 (22.6 32.2)	42.7 (38.7 50.1)	91.2 (79.5 108)
2002	14.7 (13 17.5)	7.7 (6.1 9.3)	27 (22.5 32.2)	43.6 (39.4 51.2)	93.1 (81 110.1)
2003	15.7 (13.9 18.6)	7.7 (6.1 9.3)	27 (22.5 32.2)	44.4 (39.8 52.1)	94.8 (82.3 112.2)
2004	16.6 (14.8 19.8)	7.7 (6.1 9.3)	27 (22.4 32.2)	45.1 (40.2 53)	96.4 (83.5 114.2)
2005	17.5 (15.5 21)	7.8 (6.1 9.3)	27 (22.3 32.2)	45.6 (40.5 53.7)	97.8 (84.4 116.2)
2006	18.4 (16.1 22.3)	7.8 (6 9.3)	26.9 (22.3 32.2)	46 (40.6 54.2)	99.2 (85 118)
2007	19.4 (16.6 23.6)	7.8 (6 9.3)	26.9 (22.2 32.2)	46.4 (40.6 54.7)	100.5 (85.4 119.8)
2008	20.3 (16.9 25)	7.8 (6 9.3)	26.9 (22.2 32.3)	46.6 (40.7 55.1)	101.6 (85.8 121.7)
2009	21.2 (17.2 26.5)	7.8 (6 9.3)	27 (22.2 32.3)	46.8 (40.5 55.6)	102.7 (85.9 123.6)
2010	22 (17.5 27.8)	7.8 (6 9.3)	27 (22.1 32.3)	46.9 (40.4 56.1)	103.8 (86 125.6)
2011	22.8 (17.7 29.3)	7.8 (6 9.4)	27 (22.1 32.4)	47 (40.2 56.6)	104.7 (86 127.6)
2012	23.6 (17.9 30.7)	7.8 (6 9.4)	27 (22.1 32.4)	47.1 (40.1 57)	105.6 (86.1 129.5)
2013	24.3 (18.1 32)	7.8 (6 9.4)	27 (22.1 32.4)	47.2 (40 57.4)	106.3 (86.1 131.3)

Appendix 2

Estimates of total population size, in thousands, at the beginning of each breeding season from 1984-2012, made using the model of British grey seal population dynamics fit to pup production estimates and a total population estimate from 2008, and using the new priors, including a prior on sex ratio. Numbers are posterior means followed by 95% credible intervals in brackets.

Year	North Sea	Inner Hebrides	Outer Hebrides	Orkney	Total
1984	3.9 (3.3 4.7)	4.1 (3.5 5)	19.5 (15.9 23.7)	15.3 (12.9 18.5)	42.9 (35.6 51.9)
1985	4.2 (3.5 5)	4.4 (3.7 5.3)	20.5 (16.5 25)	16.3 (13.9 19.5)	45.4 (37.6 54.8)
1986	4.5 (3.8 5.3)	4.7 (4 5.6)	21.5 (17.6 26)	17.4 (14.9 20.8)	48 (40.2 57.7)
1987	4.8 (4 5.7)	5 (4.2 5.9)	22.4 (18.2 27)	18.6 (16 22.2)	50.7 (42.5 60.7)
1988	5.1 (4.4 6.1)	5.2 (4.5 6.2)	23.1 (18.8 27.9)	20 (17.1 23.7)	53.5 (44.8 64)
1989	5.5 (4.7 6.6)	5.5 (4.7 6.5)	23.6 (19.4 28.4)	21.4 (18.4 25.4)	56 (47.2 66.8)
1990	5.9 (5.1 7)	5.8 (5 6.8)	24.1 (20 28.8)	22.9 (19.7 27.1)	58.6 (49.7 69.7)
1991	6.3 (5.5 7.5)	6 (5.2 7.1)	24.4 (20.5 29.1)	24.4 (21.1 28.9)	61.1 (52.2 72.6)
1992	6.8 (5.9 8.1)	6.2 (5.3 7.4)	24.6 (20.8 29.3)	26 (22.5 30.8)	63.7 (54.5 75.5)
1993	7.3 (6.3 8.6)	6.4 (5.5 7.6)	24.8 (21 29.5)	27.7 (24 32.7)	66.2 (56.7 78.4)
1994	7.8 (6.7 9.3)	6.6 (5.6 7.8)	24.9 (21.1 29.6)	29.5 (25.4 34.6)	68.7 (58.9 81.3)
1995	8.4 (7.2 9.9)	6.7 (5.7 8)	25 (21.2 29.7)	31.2 (26.9 36.5)	71.2 (61.1 84.2)
1996	9 (7.7 10.6)	6.8 (5.8 8.1)	25.1 (21.3 29.8)	32.9 (28.4 38.4)	73.7 (63.2 86.9)
1997	9.6 (8.3 11.4)	6.8 (5.8 8.2)	25.1 (21.3 29.8)	34.6 (29.9 40.3)	76.1 (65.4 89.6)
1998	10.3 (8.9 12.2)	6.9 (5.9 8.3)	25.2 (21.4 29.8)	36.1 (31.2 42)	78.4 (67.3 92.3)
1999	11 (9.5 13.1)	6.9 (5.9 8.3)	25.2 (21.5 29.8)	37.4 (32.3 43.5)	80.5 (69.2 94.8)
2000	11.8 (10.2 14)	7 (6 8.3)	25.2 (21.5 29.9)	38.6 (33.1 44.9)	82.5 (70.8 97.1)
2001	12.6 (10.9 14.9)	7 (6 8.4)	25.2 (21.5 29.9)	39.6 (33.8 46.1)	84.4 (72.2 99.3)
2002	13.4 (11.6 15.9)	7 (6 8.4)	25.2 (21.6 29.9)	40.4 (34.4 47.2)	86 (73.5 101.4)
2003	14.3 (12.3 17)	7 (6 8.4)	25.2 (21.6 29.9)	41 (34.8 48.1)	87.6 (74.8 103.4)
2004	15.2 (13.1 18)	7.1 (6 8.4)	25.3 (21.6 29.9)	41.6 (35.2 48.9)	89.1 (76 105.3)
2005	16.1 (13.9 19.2)	7.1 (6 8.5)	25.3 (21.6 29.9)	42 (35.6 49.6)	90.4 (77.1 107.2)
2006	17 (14.6 20.4)	7.1 (6 8.5)	25.3 (21.6 30)	42.3 (35.8 50.2)	91.7 (78.1 109)
2007	18 (15.2 21.6)	7.1 (6.1 8.5)	25.3 (21.7 30)	42.6 (36.1 50.7)	93 (79 110.8)
2008	18.9 (15.8 22.8)	7.1 (6.1 8.5)	25.3 (21.7 30)	42.8 (36.2 51.2)	94.1 (79.7 112.6)
2009	19.8 (16.3 24.1)	7.1 (6.1 8.6)	25.3 (21.7 30)	43 (36.4 51.7)	95.2 (80.4 114.4)
2010	20.6 (16.6 25.4)	7.1 (6.1 8.6)	25.3 (21.7 30.1)	43.2 (36.5 52.1)	96.2 (80.8 116.2)
2011	21.4 (16.8 26.8)	7.1 (6.1 8.6)	25.4 (21.7 30.1)	43.3 (36.6 52.6)	97.2 (81.1 118.1)
2012	22.1 (17 28.3)	7.2 (6.1 8.6)	25.4 (21.7 30.1)	43.4 (36.6 53)	98 (81.3 120)
2013	22.7 (17.1 29.9)	7.2 (6.1 8.6)	25.4 (21.7 30.2)	43.5 (36.6 53.3)	98.8 (81.4 122)

The status of UK harbour seal populations in 2013, including summer counts of grey seals

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Abstract

In August 2013, during the harbour seal moult, the Sea Mammal Research Unit (SMRU) surveys in Scotland covered almost the entire Scottish east coast, Orkney, the north coast and the far northwest coast between Cape Wrath and Ullapool. The SMRU surveys in England covered the coast of Lincolnshire, Norfolk and Suffolk. The Tees Seal Research Programme kindly provided information on seal numbers in the Tees Estuary (Woods, 2013). Data from surveys carried out in the Thames area by the Zoological Society of London are also included in the total for England. Grey seals are counted during harbour seal surveys although during the summer, grey seal counts can vary more than harbour seal counts.

From surveys carried out between 2007 and 2013, the minimum number of harbour seals counted in Scotland was **20,720** and in England & Wales **4,622** making a total count for Great Britain of **25,342** (Table 1). Including **948** harbour seals counted in Northern Ireland in 2011, the UK harbour seal total count for this period was **26,290**.

From surveys carried out between 2007 and 2013, the minimum number of grey seals counted in Scotland was **18,453** and in England & Wales **7,823** making a total count for Great Britain of **26,276** (Table 2). Including **468** grey seals counted in Northern Ireland in 2011, the UK grey seal total count for this period was **26,708**.

The 2013 Orkney count indicates that the harbour seal decline in that region is continuing at a similar rate as estimated in previous years. In the annually surveyed area within the Moray Firth (Helmsdale to Findhorn), the mean count of adults from four breeding season surveys and the single moult count were both the lowest since 2010. Given the variation in these counts over the years, this does not necessarily indicate a decline in this region. The severe decline in the Firth of Tay & Eden Estuary harbour seal SAC continued, with the 2013 moult count (50) being the lowest recorded to date, 43% lower than the 2012 count (88). This new count suggests that only 8% of the average population counted between 1990 and 2002 currently remain within this harbour seal SAC. No additional declines have been identified in other parts of the UK, for which new data is available (i.e. east coast of England, NW Scotland), where populations seem to be stable or possibly even increasing. The surveys planned for August 2014 will hopefully shed more light on the status of harbour seals along the Scottish west coast and in Shetland.

Introduction

Most surveys of harbour seals are carried out in August, during their annual moult. At this time of their annual cycle, harbour seals tend to spend longer at haul-out sites and the greatest and most consistent numbers of seals are found ashore. During a survey, however, there will be a number of seals at sea which will not be counted. Thus the numbers presented here represent the minimum number of harbour seals in each area and should be considered as an index of population size. Although harbour seals can occur all around the UK coast, they are not evenly distributed. Their main concentrations are in Shetland, Orkney, the Outer Hebrides, the west coast of Scotland, the Moray Firth and in east and southeast England, between Lincolnshire and Kent (Figure 1). Only very small, dispersed groups are found on the south and west coasts of England or in Wales.

Since 1988, SMRU's surveys of harbour seals around the Scottish coast have been carried out on an approximately five-yearly cycle, with the exception of the Moray Firth (between Helmsdale and Findhorn) and the Firth of Tay & Eden Estuary SAC which have been surveyed annually since 2002. In 2006, significant declines in harbour seal numbers were found in Shetland, Orkney and elsewhere on the UK coast (Lonergan *et al*. 2007). Between 2007 and 2009, SMRU surveyed the entire Scottish coast including a repeat survey of some parts of Strathclyde and Orkney. In 2010, Orkney was resurveyed to determine whether previously observed declines continued. A new round-Scotland survey started in 2011 and is due for completion in 2015. A complete survey of Northern Ireland and the Republic of Ireland was carried out in 2011 and 2012.

In England, the Lincolnshire and Norfolk coast holds approximately 90% of the English harbour seal population and is usually surveyed twice annually during the August moult. Since 2004, additional breeding season surveys (in early July) of harbour seals in The Wash (which lies within the August survey area) were undertaken for Natural England. The Suffolk, Essex and Kent coasts were last surveyed by SMRU during the breeding season in 2011 and during the moult in August 2013 by the Thames Harbour Seal Conservation Project, run by the Zoological Society of London.

Methods

Seals hauling out on rocky or seaweed covered shores are well camouflaged and difficult to detect. Surveys of these coastlines in Scotland are carried out by helicopter using a thermal-imaging camera. The thermal imager can detect groups of seals at distances of over 3km. This technique enables rapid, thorough and synoptic surveying of complex coastlines. In addition, since 2007, oblique photographs were obtained using a hand-held camera equipped with an image-stabilised zoom lens. Both harbour and grey seals were digitally photographed and the images used to classify group composition. The grey seal counts from these images have previously been used to inform the models used to estimate the total grey seal population size (Lonergan *et al*. 2011, SCOS BP 10/4).

Surveys of the estuarine haul-out sites on the east coast of Scotland and England were by fixed-wing aircraft using hand-held oblique photography. On sandbanks, where seals are relatively easily located, this survey method is highly cost-effective.

To maximise the counts of seals on shore and to minimise the effects of environmental variables, surveys are restricted to within two hours before and two hours after the time of local low tides (derived from POLTIPS, National Oceanographic Centre, NERC) occurring between approximately 12:00hrs and 18:00hrs. Surveys are not carried out in persistent or moderate to heavy rain because seals will increasingly abandon their haul-out sites and return into the water, and because the thermal imager cannot ‘see’ through rain.

In southeast England, from Suffolk to Kent, the Thames Harbour Seal Conservation Project coordinated August surveys by air, from boat and from land on three days in August 2013 (Barker *et al*., 2014).

Results and Discussion

1. Minimum population size estimate for harbour seals in the UK

The overall distribution of harbour seals around the British Isles from August surveys carried out between 2007 and 2013 is shown in Figure 1. For ease of viewing at this scale, counts have been aggregated by 10km squares.

The most recent minimum harbour seal population estimates (i.e. counts between 2007 and 2013) for UK seal management units (SMUs) are provided in Table 1 and are compared with two previous periods (2000 to 2006 and 1996 to 1997). Estimates for Ireland are also given for the two most recent periods.

Mean values were used for any areas where repeat counts were available (primarily in eastern England and occasionally the Moray Firth).

The most recent minimum estimate of the number of harbour seals in Scotland, obtained from counts carried out between 2007 and 2013, is **20,720** (Table 1). This is 11% down from the 2000-2006 count and 30% down from the 1996-1997 count (Table 1). Since 2001, significant reductions have been recorded in

Shetland, Orkney and along the north and east coasts of Scotland (Lonergan *et al*. 2007). Numbers in the western seal management units do not appear to be declining.

The most recent minimum estimate for England & Wales, obtained from surveys carried out mainly in 2013, is **4,622** (Table 1). This is 52% higher than the 2005-2006 count and 41% higher than the 1996-1997 count (which includes some data from 1995).

The 2011 count for Northern Ireland of **948** was 25% lower than the previous complete count in 2002 (1,267).

The sum of all the most recent counts carried out between 2007 and 2013 gives a UK total count of **26,290** harbour seals (Table 1).

1.1 Grey seals in the UK during the harbour seal moult in August

Grey seals are counted in all harbour seal surveys, but because they are thought to be significantly more variable than harbour seal counts in August, they have not been fully reported until this Briefing Paper. In conjunction with grey seal telemetry data, the grey seal summer counts from 2007 and 2008 have been used to calculate an independent estimate of the size of the grey seal population (Lonergan *et al*. 2011).

The overall distribution of grey seals from August harbour seal surveys carried out between 2007 and 2013 is shown in Figure 2. For ease of viewing at this scale, counts have been aggregated by 10km squares. The most recent estimate of the number of grey seals in Scotland, obtained from August counts carried out between 2007 and 2013 is **18,453** (Table 2). This is 11% lower than the total Scotland count of 20,813 from August surveys between 2000 and 2006.

2. Harbour seals in Scotland

The survey area for August 2013 comprised the east and north coast of Scotland, Orkney and the north-west coast of Scotland from Cape Wrath to Rubha Reidh. All areas were covered with the exception of the south-easternmost section between the English Border and Aberlady Bay and the final section in the south of the 'West Scotland – North' SMU subdivision between Ullapool and Rubha Reidh.

Figure 3 shows when each part of the Scottish coast was last surveyed between 2007 and 2013. Areas surveyed in 2013 are in black; areas in red were last surveyed in 2007 and most urgently require updating.

The most up to date distribution of harbour seals in Scotland, from surveys between 2007 and 2013, is shown in Figure 4. Grey seals are also counted during harbour seal surveys and their distribution in Scotland, over the same time period, is in Figure 5.

The trends in counts of harbour seals in different Seal Management Areas in Scotland, from surveys carried out between 1996 and 2013 are shown in Figure 7. Harbour seal counts from the most recent surveys and from two previous survey periods (2000 to 2006 and 1996 to 1997) are in Table 1.

In Orkney, the new low of 1,865, counted in August 2013, is 76% lower than the last relatively high count recorded in 2001 (7,752). This is equivalent to an average annual decline of approximately 11%, and indicates that the decline first identified in 2006 is continuing at a fairly consistent rate.

2.1 Moray Firth

Detailed breeding and moulting season counts of harbour seals in a subarea of the Moray Firth (from Loch Fleet to Ardersier) were collected annually by Aberdeen University's Lighthouse Field Station between 1988 and 2005. These ground-based counts are shown in Figure 9 (breeding season counts, not including pups) and Figure 10 (moulting season counts). SMRU's aerial survey counts for the same areas are included, together with counts from adjacent haul-out sites which lie to the north-east of Loch Fleet and to the east of Ardersier (Table 3, Figure 8). A detailed view of the part of the Moray Firth surveyed by SMRU, together with the August counts of harbour and grey seals in 2013, is shown in Figure 11.

Counts of grey seals from SMRU's August surveys of the Moray Firth are shown in Table 4.

2.1.1 Moray Firth – harbour seal moult season counts (August)

SMRU's August aerial surveys of harbour seals in the Moray Firth started in August 1992 and the counts are shown in Table 3 with the trends in different parts of the Moray Firth in Figure 8. The counts represent a combination of both thermal imaging and fixed-wing surveys of the area. Between the mid-1990s and 2007, counts indicated a decline in the Moray Firth harbour seal population. This may, at least in part, have been due to a bounty system for seals which operated in the area at the time (Thompson *et al*., 2007; Matthiopoulos *et al*., 2014). There is considerable variability in the August total counts for the entire Moray Firth and, since 2007, no clear overall trend is evident. However, there have been some obvious changes within smaller parts of the Moray Firth. Following a significant decline between 1992 (662) and 2002 (220), harbour seal numbers within the Dornoch Firth and Morrich Mor SAC now appear to be relatively stable, although the 2013 count (143) was the lowest recorded. A decline has also been observed in the Beauly Firth where over 200 harbour seals were regularly counted in the 1990s, but only between 30 and 60 counted since 2011. In contrast, harbour seal numbers in Loch Fleet have been slowly increasing since the 1990s, with 135 in August 2013 the highest count recorded during SMRU's August aerial surveys. The most noticeable increase in recent years, however, was at Culbin Sands, between Findhorn and Nairn. Whereas up until 2009, harbour seal counts rarely reached double figures, 174 were recorded at Culbin in August 2013.

Causes for these changes have not been identified, but it is possible that the ever changing sandbank system in the Beauly Firth has become less suitable for seals to haul out compared with other available sites nearby.

2.1.2 Moray Firth – harbour seal breeding season counts (June & July)

During the 2013 breeding season, SMRU completed four aerial surveys of harbour seals in the Moray Firth between 16th June and 14th July. The mean number of adults counted during these surveys, with standard errors, is shown in Figure 9. Following a long period of decline in breeding season haul-out group size from 1993 to 2007 and an increase in 2009 and 2010, numbers have declined over the last three years. As during the moult, this is partly due to a significant reduction in seals using the Beauly Firth which used to be the main pupping site in the Moray Firth. Whereas the maximum pup count in 2010 was 172, it was never higher than 10 in 2013. The mean count for the 2013 breeding season surveys between Helmsdale and Findhorn was 663, 23% lower than the 2013 moult count of 858.

2.2 Firth of Tay & Eden Estuary Special Area of Conservation (SAC)

The Firth of Tay and Eden Estuary SAC is shown in Figure 12 with the distribution and numbers of harbour seals counted during the August 2013 survey (bold colours) compared with the numbers counted in the August 2000 survey (soft colours).

The 2013 harbour seal moult count for the SAC (50) was 43% lower than the 2012 count of 88 (Figure 14; Table 5). The 2013 count is a new all-time low for this harbour seal SAC and represents only 8% of the mean from counts between 1990 and 2002 (641). Harbour seals in this area are of sufficient concern that Marine Scotland has not issued any licences to shoot harbour seals within the East Scotland Management Area since 2010.

The numbers of grey seals counted in the Firth of Tay & Eden Estuary SAC during harbour seal moult surveys are in Table 6.

3. Harbour seal surveys in England & Wales

3.1. England & Wales – harbour seal moult season counts (August)

The coast of England and Wales has been divided into three management units (Figure 1). In Northeast England, small numbers of harbour seals are found at Holy Island and in the Tees Estuary. The 2013 count for Northeast England was 83, a combined count from 2008 (Holy Island) and 2013 (Tees Estuary; Woods, 2013). Harbour seals in the Tees Estuary are monitored by the Industry Nature Conservation Association (INCA). The very slow increase in numbers seems to be continuing, with the August 2013 mean count of 74 being the highest since recording began in 1988 (Woods 2013). Low but increasing numbers of pups were born in the Tees Estuary (23 pups born in 2013 with 22 surviving to weaning; Woods, 2013).

The great majority of English harbour seals are found in Southeast England (Figure 1). In 1988, the previously increasing numbers of harbour seals in The Wash declined by approximately 50% as a result of the phocine distemper virus (PDV) epidemic. Following the epidemic, from 1989, the area has been surveyed once or twice annually in the first half of August (Table 7, Figure 16). After recovering to 1988 levels by 2001, the population was hit by another PDV outbreak in 2002. It was reduced by around 20% but had recovered to pre-epidemic levels by 2012.

One aerial survey of harbour seals was carried out by SMRU in Lincolnshire and Norfolk during August 2013 (Table 6). The 2013 count for this area from Donna Nook to Scroby Sands (4,022) was 4% lower than the 2012 count (4,189). The Zoological Society of London surveyed the wider Thames area between Hamford Water (in Essex) and Goodwin Sands (off the Kent coast) and counted 482 harbour seals (Barker *et al*. 2014), the highest count recorded for this area.

The combined counts for the Southeast England management unit (Flamborough Head to Newhaven) in 2013 (4,504) was very similar to the previous equivalent count (4,568 combination from 2010 and 2012; Table 6). Although the Southeast England population has returned to its pre-2002 epidemic levels, it is still lagging behind the rapid recovery of the harbour seal population in the Wadden Sea where counts have increased from 10,800 in 2003 to 26,788 in 2013 (Reijnders *et al*., 2003; Trilateral Seal Expert Group, 2013), equivalent to an average annual growth rate of 9.5% over the last ten years.

No dedicated harbour seal surveys are routinely carried out in the West England & Wales management unit. Estimates given in Table 1 are derived from compiling information from various different sources.

3.2. England & Wales – harbour seal breeding season counts (June & July)

The only regular harbour seal breeding season surveys in England & Wales are the annual SMRU aerial surveys around The Wash. A single survey conducted around the expected peak date (6 July 2013) produced counts of 1,308 pups and 3,345 older seals (1+ age classes) compared with 1,496 pups and 3,551 older seals in 2012 and 1,106pups and 3,283 older seals in 2011. Estimated peak pup counts have increased at an average rate of 9% p.a. since 2003 although there is considerable variation about the fitted exponential (R^2=0.8).

5. UK harbour seal surveys for 2014

5.1 Harbour seal surveys in 2014 – breeding season

Four of five planned breeding season fixed-wing surveys were carried out in the Moray Firth in June and July 2014. One survey was not attempted due to persistent heavy rain on the possible survey days. The results will be presented to SCOS in 2015.

As in 2013, a single breeding season fixed-wing survey was carried out in The Wash on 30th June 2014. The results will be presented to SCOS in 2015.

5.2 Harbour seal surveys in 2014 – moult season

In Scotland in 2014, a large section of the Scottish west coast, from Ullapool to the southern tip of the Mull of Kintyre (including the islands) will be surveyed by helicopter, weather permitting. The same methods will be used as in previous years, including both thermal imagery and high resolution digital still images.

As in previous years, a single fixed-wing survey will be carried out during August in the Moray Firth (between Helmsdale and Findhorn) as well as in the Firth of Tay & Eden Estuary SAC.

In Southeast England SMRU intends to carry out two August surveys of the coast between Donna Nook and Scroby Sands. In addition, the Zoological Society of London intends to carry out two surveys of the Essex and Kent coasts.

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We are also extremely grateful for, and utterly dependent on, the technical expertise so enthusiastically provided by the companies supplying the survey pilots and aircrafts: PDG Helicopters, Giles Aviation, Highland Aviation and Caledonian Air Surveys Ltd.

We would like to thank all organisations who have helped to make this overview of seal distribution during the summer as comprehensive as possible by sharing count data from areas where SMRU don't carry out regular surveys: Industry Nature Conservation Agency, Zoological Society London, Chichester Harbour Conservancy, Hampshire and Isle of Wight Wildlife Trust, Langstone Harbour Board, Cornwall Seal Group, Natural England, Wildlife Trust of South and West Wales, Royal Society for the Protection of Birds, Natural Resources Wales (previously Countryside Council for Wales), Hilbre Bird Observatory.

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Table 1. The most recent August counts of harbour seals at haul-out sites in Britain and Ireland by seal management unit compared with two previous periods, in 1996 and 1997 and between 2000 and 2006. Values that have been updated with 2013 counts are highlighted with a grey background.

Seal Management Unit / Country		Harbour seal counts							
		2007-2013			2000-2006			1996-1997	
1 Southwest Scotland		834	(2007)		623	(2005)		929	(1996)
2a West Scotland - South		5,915	(2007; 2009)		7,003	(2000; 2005)		5,651	(1996)
2b West Scotland - Central		4,004	(2007; 2008)		3,956	(2005)		2,700	(1996)
2c West Scotland - North		1,138	(2008; 2013)		709	(2005)		460	(1996-1997)
2 West Scotland	a	11,057	(2007-2009; 2013)		11,668	(2000; 2005)		8,811	(1996-1997)
3 Western Isles		2,739	(2011)		1,981	(2003; 2006)		2,820	(1996)
4a North Coast		73	(2013)		146	(2005-2006)		265	(1997)
4b Orkney		1,865	(2013)		4,238	(2006)		8,522	(1997)
4 North Coast & Orkney		1,938	(2013)		4,384	(2005-2006)		8,787	(1997)
5 Shetland		3,039	(2009)		3,038	(2006)		5,994	(1997)
6 Moray Firth		898	(2008; 2011; 2013)		1,028	(2005-2006)		1,409	(1997)
7 East Scotland		215	(2007; 2013)		667	(2005-2006)		764	(1997)
SCOTLAND TOTAL		**20,720**	(2007-2009; 2011; 2013)		**23,389**	(2000; 2003; 2005-2006)		**29,514**	(1996-1997)
8 Northeast England	b	83	(2008; 2013)	*	62	(2005-2006)	*	54	(1997)
9 Southeast England	c	4,504	(2013)		2,964	(2005-2006)		3,217	(1995; 1997)
10 West England & Wales	d	35	(estimate)		20	(estimate)		15	(estimate)
ENGLAND & WALES TOTAL		**4,622**	(2008; 2013)		**3,046**	(2005-2006)		**3,286**	(1995; 1997)
BRITAIN TOTAL		**25,342**	(2007-2009; 2011; 2013)		**26,435**	(2000; 2003; 2005-2006)		**32,800**	(1995-1997)
NORTHERN IRELAND TOTAL	e	**948**	(2011)		**1,176**	(2002; 2006)			
UK TOTAL		**26,290**	(2007-2009; 2011; 2013)		**27,611**	(2000; 2002-2003; 2005-2006)			
REPUBLIC OF IRELAND TOTAL	f	**3,489**	(2011-2012)		**2,955**	(2003)			
BRITAIN & IRELAND TOTAL		**29,779**	(2007-2009; 2011-2013)		**30,566**	(2000; 2002-2003; 2005-2006)			

SOURCES - Most counts were obtained from aerial surveys conducted by SMRU and were funded by Scottish Natural Heritage (SNH) and the Natural Environment Research Council (NERC). Exceptions are:

[a] Part of the West Scotland survey in 2009 funded by Scottish Power.

[b] The Tees data collected and provided by the Industry Nature Conservation Association (Woods, 2013). The 2008 survey from Coquet Island to Berwick funded by the Department of Energy and Climate Change (DECC, previously DTI).

[c] Essex & Kent data for 2013 collected and provided by the Zoological Society London (Barker *et al*., 2014).

[d] No dedicated harbour seal surveys in this management unit and only sparse info available. Estimates compiled from counts shared by other organisations (Chichester Harbour Conservancy) or found in various reports & on websites (Boyle, 2012; Hilbrebirdobs.blogspot.co.uk, 2012, 2013; Sayer, 2010a, 2010b, 2011; Sayer *et al.,* 2012; Westcott, 2002). Apparent increases may partly be due to increased reporting and improved species identification.

[e] Surveys carried out by SMRU and funded by Northern Ireland Environment Agency (NIEA) in 2002 & 2011 (Duck, 2006; Duck & Morris, 2012) and Marine Current Turbines Ltd in 2006-2008 & 2010 (SMRU Ltd, 2010).

[f] Surveys carried out by SMRU and funded by the National Parks & Wildlife Service (Cronin *et al*., 2004; Duck & Morris, 2013a, 2013b).

*Northumberland coast south of Farne Islands not surveyed in 2005 & 1997, but no harbour seal sites known here.

Table 2. The most recent August counts of grey seals at haul-out sites in Britain and Ireland by seal management unit compared with two previous periods. Values that have been updated with 2013 counts are highlighted with a grey background. Grey seal summer counts are known to be more variable than harbour seal summer counts. Therefore caution is advised when interpreting these numbers.

Seal Management Unit / Country		Grey seal counts						
		2007-2013			2000-2006		1996-1997	
1 Southwest Scotland		374	(2007)		206	(2005)	75	(1996)
2a West Scotland - South		1,774	(2007; 2009)		1,771	(2000; 2005)	2,125	(1996)
2b West Scotland - Central		561	(2007; 2008)		361	(2005)	931	(1996)
2c West Scotland - North		365	(2008; 2013)		251	(2005)	379	(1996-1997)
2 West Scotland	a	2,700	(2007-2009; 2013)		2,383	(2000; 2005)	3,435	(1996-1997)
3 Western Isles	*	2,518	(2011)		3,528	(2003; 2006)	4,062	(1996)
4a North Coast		195	(2013)		576	(2005-2006)	597	(1997)
4b Orkney		7,884	(2013)		9,579	(2006)	8,830	(1997)
4 North Coast & Orkney		8,079	(2013)		10,155	(2005-2006)	9,427	(1997)
5 Shetland		1,536	(2009)		1,371	(2006)	1,724	(1997)
6 Moray Firth		1,311	(2008; 2011; 2013)		1,272	(2005-2006)	551	(1997)
7 East Scotland		1,935	(2007; 2013)		1,898	(2005-2006)	2,328	(1997)
SCOTLAND TOTAL		**18,453**	(2007-2009; 2011; 2013)		**20,813**	(2000; 2003; 2005-2006)	**21,602**	(1996-1997)
8 Northeast England	b	2,345	(2008; 2013)	†	1,100	(2005-2006)		
9 Southeast England	c	4,178	(2013)		2,266	(2005-2006)		
10 West England & Wales	d	1,300	(estimate)		1,150	(estimate)		
ENGLAND & WALES TOTAL		**7,823**	(2008; 2013)		**4,516**	(2005-2006)		
BRITAIN TOTAL		**26,276**	(2007-2009; 2011; 2013)		**25,329**	(2000; 2003; 2005-2006)		
NORTHERN IRELAND TOTAL	e	**468**	(2011)		**275**	(2002; 2006)		
UK TOTAL		**26,744**	(2007-2009; 2011; 2013)		**25,604**	(2000; 2002-2003; 2005-2006)		
REPUBLIC OF IRELAND TOTAL	f	**2,964**	(2011-2012)		**1,309**	(2003)		
BRITAIN & IRELAND TOTAL		**29,708**	(2007-2009; 2011-2013)		**26,913**	(2000; 2002-2003; 2005-2006)		

SOURCES - Most counts were obtained from aerial surveys conducted by SMRU and were funded by Scottish Natural Heritage (SNH) and the Natural Environment Research Council (NERC). Exceptions are:

- a Part of the West Scotland survey in 2009 funded by Scottish Power.
- b The Tees data collected and provided by the Industry Nature Conservation Association (Woods, 2013). The 2008 survey from Coquet Island to Berwick funded by the Department of Energy and Climate Change (DECC, previously DTI).
- c Essex & Kent data for 2013 collected and provided by the Zoological Society London (Barker et al., 2014).
- d No SMRU surveys in this management unit but some data available. Estimates compiled from counts shared by other organisations (Natural Resources Wales, RSPB) or found in various reports & on websites (Boyle, 2012; Büche & Stubbings, 2014; Hilbrebirdobs.blogspot.co.uk, 2012, 2013; Leeney *et al*., 2010; Sayer, 2010b, 2011, 2012a, 2012b; Sayer *et al*., 2012; Westcott, 2002, 2009; Westcott & Stringell, 2004). Apparent increases may partly be due to increased reporting.
- e Surveys carried out by SMRU and funded by Northern Ireland Environment Agency (NIEA) in 2002 & 2011 (Duck, 2006; Duck & Morris, 2012) and Marine Current Turbines Ltd in 2006-2008 & 2010 (SMRU Ltd, 2010).
- f Surveys carried out by SMRU and funded by the National Parks & Wildlife Service (Cronin et al., 2004; Duck & Morris, 2013a, 2013b).

* During the 2011 survey, warm weather probably kept hundreds of grey seals from hauling out at the Monach Isles.

† Northumberland coast south of Farne Islands not surveyed in 2005, so count may be incomplete.

Table 3. August counts of harbour seals in the Moray Firth, 1992-2013. Mean value if more than one count in any year; red = lowest count, green = highest count. Data are from aerial surveys by the Sea Mammal Research Unit. Since 2006, all surveys incorporated hand-held oblique digital photography. See Figure 11 for a map showing the 2013 distribution of seals in the Moray Firth and Figure 8 for a histogram of these data.

	Area	1992	1993	1994	1997	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	Survey method	fw	fw	fw	ti	fw	fw &ti	fw	2fw	2fw &1ti	fw &ti	ti	fw &ti	fw	fw	ti	fw	fw
(MEAN) COUNTS	Duncansby Head to Helmsdale		2		1					1			1					
	Helmsdale to Brora		92		193		188			113	150	54	73	19	101	87	102	70
	Loch Fleet		16		27	33	59	56	64	71	80	83	82	65	114	113	133	135
	Dornoch Firth (SAC)	662		542	593	405	220	290	231	191	257	144	145	166	219	208	157	143
	Cromarty Firth	41		95	95	38	42	113	88	106	106	102	90	90	140	101	144	63
	Beauly Firth (incl. Milton)	220		203	219	204	66	151	178	127	176	146	150	85	140	57	60	30
	Ardersier (incl. Eathie)			221	234	191	110	205	202	210	197	154	145	277	362	195	183	199
	Culbin & Findhorn			58	46	111	144	167	49	93	58	79	92	73	123	163	254	218
	Burghead to Fraserburgh			0	1					3		0				29		39
TOTALS	Dornoch Firth to Ardersier			1,061	1,141	838	438	759	699	634	736	546	530	618	861	561	544	435
	Loch Fleet to Ardersier				1,168	871	497	815	763	705	816	629	612	683	975	674	677	570
	Loch Fleet to Findhorn				1,214	982	641	982	812	798	874	708	704	756	1,098	837	931	788
	Helmsdale to Findhorn				1,407		829			911	1,024	762	777	775	1,199	924	1,033	858
	Moray Firth SMA *				1,409		831			915	1,028	763	778	776	1,200	954	1,063	898

* For years where only the main area was surveyed (i.e. Helmsdale to Findhorn), the most recent counts for the outlying areas are used to give a total for the Moray Firth Seal Management Area.
fw, fixed-wing survey; ti, thermal imager helicopter survey; SMA, Seal Management Area.

Table 4. August counts of grey seals in the Moray Firth, 1992-2013. Mean value if more than one count in any year; red = lowest count, green = highest count per area. Data are from aerial surveys by the Sea Mammal Research Unit. Since 2006, all surveys were by hand-held oblique digital photography. See Figure 11 for a map showing the 2013 distribution of seals in the Moray Firth.

	Area	1992	1993	1994	1997	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	Survey method	fw	fw	fw	ti	fw	fw &ti	fw	2fw	2fw &1ti	fw &ti	ti	fw &ti	fw	fw	ti	fw	fw
(MEAN) COUNTS	Duncansby Head to Helmsdale *		33		0					59			9			15		
	Helmsdale to Brora				3		6			111	102	52	449	72	635	156	316	81
	Loch Fleet		0		0	0	0	0	0	0	1	3	1	0	7	7	20	18
	Dornoch Firth (SAC)	233		903	456	121	321	79	473	431	748	516	523	819	717	679	74	604
	Cromarty Firth	9		0	0	0	0	0	0	0	1	0	0	0	1	2	1	3
	Beauly Firth (incl. Milton)	8		2	3	8	0	0	0	0	3	4	0	0	2	3	1	5
	Ardersier (incl. Eathie)			36	24	85	0	3	44	55	142	74	142	94	297	74	24	109
	Culbin & Findhorn			0	0	0	0	10	0	11	11	28	75	58	58	179	121	218
	Burghead to Fraserburgh			30	65					205		61				18		258
TOTALS	Dornoch Firth to Ardersier			941	483	214	321	82	517	486	894	594	665	913	1,017	758	100	721
	Loch Fleet to Ardersier				483	214	321	82	517	486	895	597	666	913	1,024	765	120	739
	Loch Fleet to Findhorn				483	214	321	92	517	497	906	625	741	971	1,082	944	241	957
	Helmsdale to Findhorn				486		327			608	1,008	677	1,190	1,043	1,717	1,100	557	1,038
	Moray Firth SMA †				551		392			872	1,272	797	1,260	1,113	1,787	1,133	590	1,311

* In 2011, Duncansby Head to Wick was not surveyed. Therefore the 15 grey seals given for the northern most area in 2011 include 7 counted in 2008.

† For years where only the main area was surveyed (i.e. Helmsdale to Findhorn), the most recent counts for the outlying areas are used to give a total for the Moray Firth Seal Management Area.

fw, fixed-wing survey; ti, thermal imager helicopter survey; SMA, Seal Management Area.

Table 5. August counts of harbour seals in the Firth of Tay & Eden Estuary harbour seal SAC, 1990-2013. Mean value if more than one count in any year; red = lowest count, green = highest count per area. Data are from aerial surveys by the Sea Mammal Research Unit. Since 2006, all surveys were by hand-held oblique digital photography. See Figure 12 for a map showing the 2013 distribution of harbour seals in the SAC and Figure 14 for a histogram of these data.

	Area	1990	1991	1992	1994	1997	2000	2002	2003	2005	2006	2007	2008	2009	2010	2011	2012	2013
	Survey method	1fw	1fw	1fw	1fw	1ti	1fw	1fw	1fw	2fw ,1ti	1fw	1fw ,1ti	2fw	1fw	1fw	1fw	1fw	1ti
(MEAN) COUNTS	Upper Tay	27	73	148	89	113	115	51	83	91	91	63	49	45	41	16	40	36
	Broughty Ferry	77	83	97	64	35	52	0	90	51	31	27	13	28	15	18	16	3
	Buddon Ness	13	86	72	53	0	113	109	142	25	96	64	27	8	23	11	8	10
	Abertay & Tentsmuir	319	428	456	289	262	153	167	53	63	34	31	50	8	9	0	5	0
	Eden Estuary	31	0	0	80	223	267	341	93	105	90	90	83	22	36	32	19	1
	SAC total	467	670	773	575	633	700	668	461	335	342	275	222	111	124	77	88	50

fw, fixed-wing survey; ti, thermal imager helicopter survey; SAC, Special Area of Conservation

Table 6. August counts of grey seals in the Firth of Tay & Eden Estuary harbour seal SAC, 1990-2013. Mean value if more than one count in any year; red = lowest count, green = highest count per area. Data are from aerial surveys by the Sea Mammal Research Unit. Since 2006, all surveys were by hand-held oblique digital photography. See Figure 13 for a map showing the 2013 distribution of seals in the SAC and Figure 15 for a histogram of these data.

	Area	1990	1991	1992	1994	1997	2000	2002	2003	2005	2006	2007	2008	2009	2010	2011	2012	2013
	Survey method	1fw	1fw	1fw	1fw	1ti	1fw	1fw	1fw	2fw ,1ti	1fw	1fw ,1ti	2fw	1fw	1fw	1fw	1fw	1ti
(MEAN) COUNTS	Upper Tay	0	0	18	20	61	64	78	50	42	22	27	41	55	98	16	39	127
	Broughty Ferry	0	3	0	9	0	0	0	16	0	8	1	4	0	0	2	3	0
	Buddon Ness	0	0	1	104	0	101	0	33	11	25	85	4	0	12	22	13	18
	Abertay & Tentsmuir	912	1,546	1,191	1,335	1,820	2,088	1,490	1,560	763	1,267	1,375	442	395	1,406	1,265	1,111	323
	Eden Estuary	0	0	16	0	10	0	25	4	27	57	31	17	0	39	17	36	14
	SAC total	912	1,549	1,226	1,468	1,891	2,253	1,593	1,663	843	1,379	1,519	508	450	1,555	1,322	1,202	482

fw, fixed-wing survey; ti, thermal imager helicopter survey; SAC, Special Area of Conservation

Table 7. August counts of harbour seals on the English east coast, 1988-2013. In years where more than one survey was carried out, values are means with number of surveys in parentheses. Blank grey cells mean 'no survey was carried out'.

	Northeast England		Southeast England				
Year	N'umberland	The Tees	Donna Nook	The Wash	Blakeney Point	Scroby Sands	Essex & Kent
1988			173	3,053	701		
1989		16 (31)	126	1,549 (2)	307		
1990		23 (31)	57	1,543	73		
1991		24 (31)		1,398 (2)			
1992		27 (31)	18	1,671 (2)	217		
1993		30 (31)	88	1,884	267		
1994	13	35	103 (2)	2,005 (2)	196	61	
1995		33 (31)	115	2,084 (2)	415 (2)	49	130
1996		42 (31)	162	2,151	372	51	
1997	12	42 (31)	251 (2)	2,466 (2)	311 (2)	65 (2)	
1998		41 (31)	248 (2)	2,374 (2)	637 (2)	52	
1999		36 (31)	304 (2)	2,392 (2)	659 (2)	72 (2)	
2000	10	59 (31)	390 (2)	2,779 (2)	895	47 (2)	
2001		59 (31)	233	3,194	772	75	
2002		52 (31)	341	2,977 (2)	489 (2)		
2003		38 (31)	231	2,513 (2)	399	38	180
2004		40 (31)	294 (2)	2,147 (2)	646 (2)	57 (2)	
2005	17	50 (31)	421 (2)	1,946 (2)	709 (2)	56 (2)	101
2006		45 (31)	299	1,695	719	71	
2007	7	43 (31)	214	2,162	550		
2008	9	41 (31)	191 (2)	2,011 (2)	581 (2)	81 (2)	319
2009		49 (31)	267 (2)	2,829 (2)	372	165 (2)	
2010		53 (31)	176 (2)	2,586 (2)	391	201 (2)	379
2011		57 (31)	205	2,894	349	119	
2012		63 (31)	192 (2)	3,372 (2)	409	216	
2013		74 (31)	396	3,174	304	148	482

SOURCE - Counts from SMRU aerial surveys using a fixed-wing aircraft funded by NERC except where stated otherwise:
Northumberland - One complete survey in 2008 (funded by DECC (previously DTI). Helicopter surveys with thermal imager from Farne Islands to Scottish border in 1997, 2005 & 2007. Fixed-wing surveys of Holy Island only in 1994 & 2000.
The Tees - Ground counts by Industry Nature Conservation Agency (Woods, 2013). Single SMRU fixed-wing count in 1994.
Southeast England - All SMRU aerial surveys, except for Essex & Kent 2013: data from surveys (aerial/by boat/from land) carried out by the Zoological Society of London (Barker et al., 2014). The 130 for 1995 are an estimate based on a partial SMRU aerial survey.

Table 8. August counts of grey seals on the English east coast, 1995-2013. In years where more than one survey was carried out, values are means with number of surveys in parentheses. Blank grey cells mean 'no survey was carried out'.

	Northeast England		Southeast England				
Year	N'umberland	The Tees	Donna Nook	The Wash	Blakeney Point	Scroby Sands	Essex & Kent
1995		10	123	66 (2)	18 (2)	32	
1996		11	119	60	11	46	
1997	603	10	289 (2)	49 (2)	45 (2)	34 (2)	
1998		11	174 (2)	53 (2)	33 (2)	23	
1999		12	317 (2)	57 (2)	14 (2)	89 (2)	
2000	568	11	390	40 (2)	17	40 (2)	
2001		11	214	111	30	70	
2002		12	291	75 (2)	11 (2)		
2003		11	232 (2)	58 (2)	18	36	96
2004		13	609 (2)	30 (2)	10 (2)	93 (2)	
2005	1,092	12 (31)	927 (2)	49 (2)	86 (2)	106 (2)	
2006		8 (31)	1,789	52	142	187	
2007	1,907	8 (31)	1,834	42			
2008	2,338	12 (31)	2,068 (2)	68 (2)	375 (2)	137 (2)	160
2009		12 (31)	1,329 (2)	118 (2)	22	157 (2)	
2010		14 (31)	2,188 (2)	240 (2)	49 (2)	292 (2)	393
2011		14 (31)	1,930	142	300	323	
2012		18 (31)	4,978	258 (2)	65		
2013		16 (31)	3,474	219	63	219	203

SOURCE - Counts from SMRU aerial surveys using a fixed-wing aircraft funded by NERC except where stated otherwise:
Northumberland - One complete survey in 2008 (funded by DECC (previously DTI). Helicopter surveys with thermal imager from Farne Islands to Scottish border in 1997, 2005 & 2007. Fixed-wing surveys of Holy Island only in 1994 & 2000.
The Tees - Ground counts by Industry Nature Conservation Agency (Woods, 2013). For years prior to 2005, only monthly maximums are available for grey seals. For these years, the given values are estimates calculated using the mean relationship of mean to maximum counts from 2005-2013.
Southeast England - All SMRU aerial surveys, except for Essex & Kent 2013: data from surveys (aerial/by boat/from land) carried out by the Zoological Society of London (Barker et al., 2014).

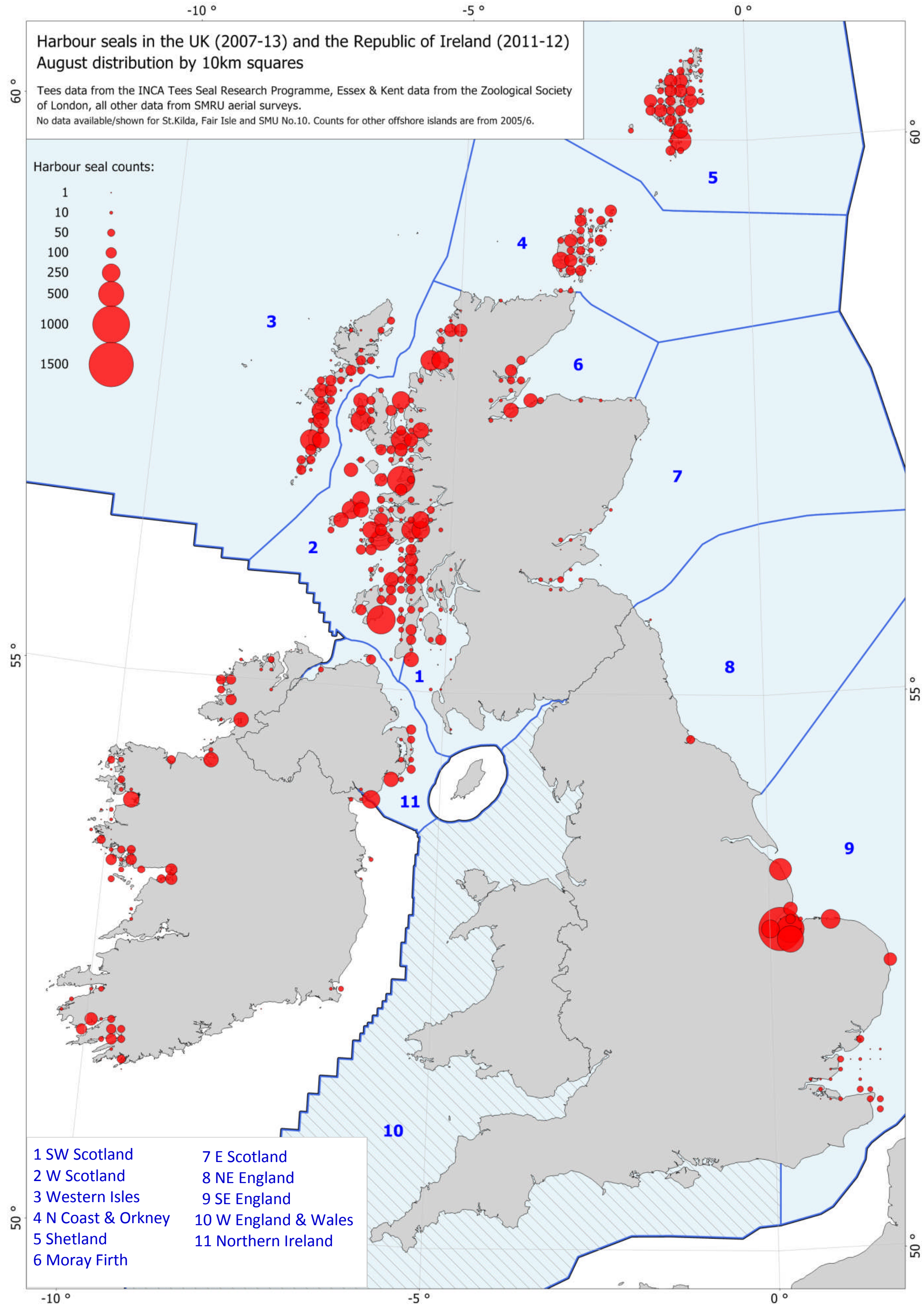

Figure 1. August distribution of harbour seals around the British Isles. Very small numbers of harbour seals (<50) are anecdotally but increasingly reported for the West England & Wales management unit, but are not included on this map.

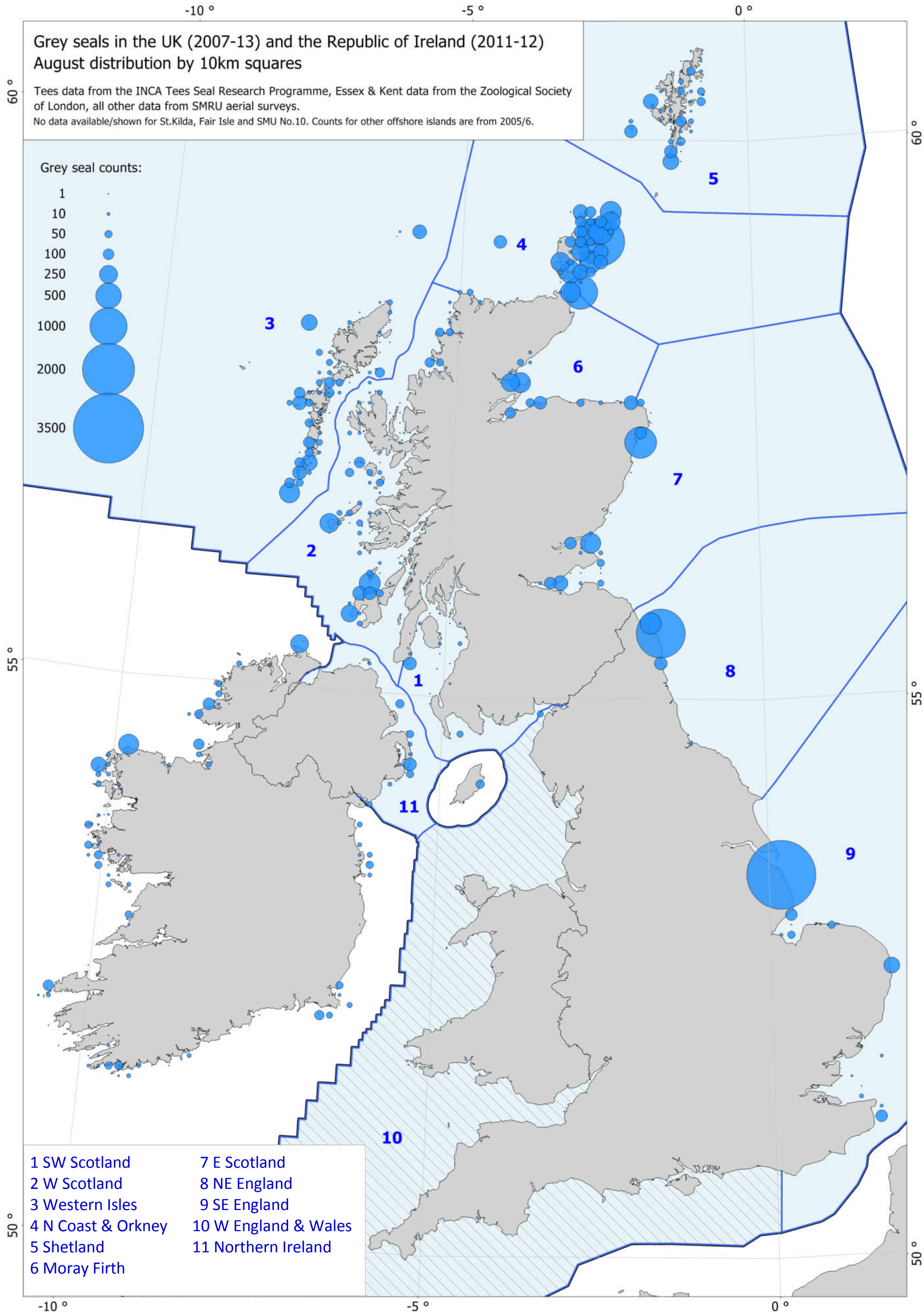

Figure 2. August distribution of grey seals around the British Isles. Only few August counts are available for grey seals in the West England & Wales management unit. Current estimates would add approximately 1,300 animals for this unit, but these are not included on this map.

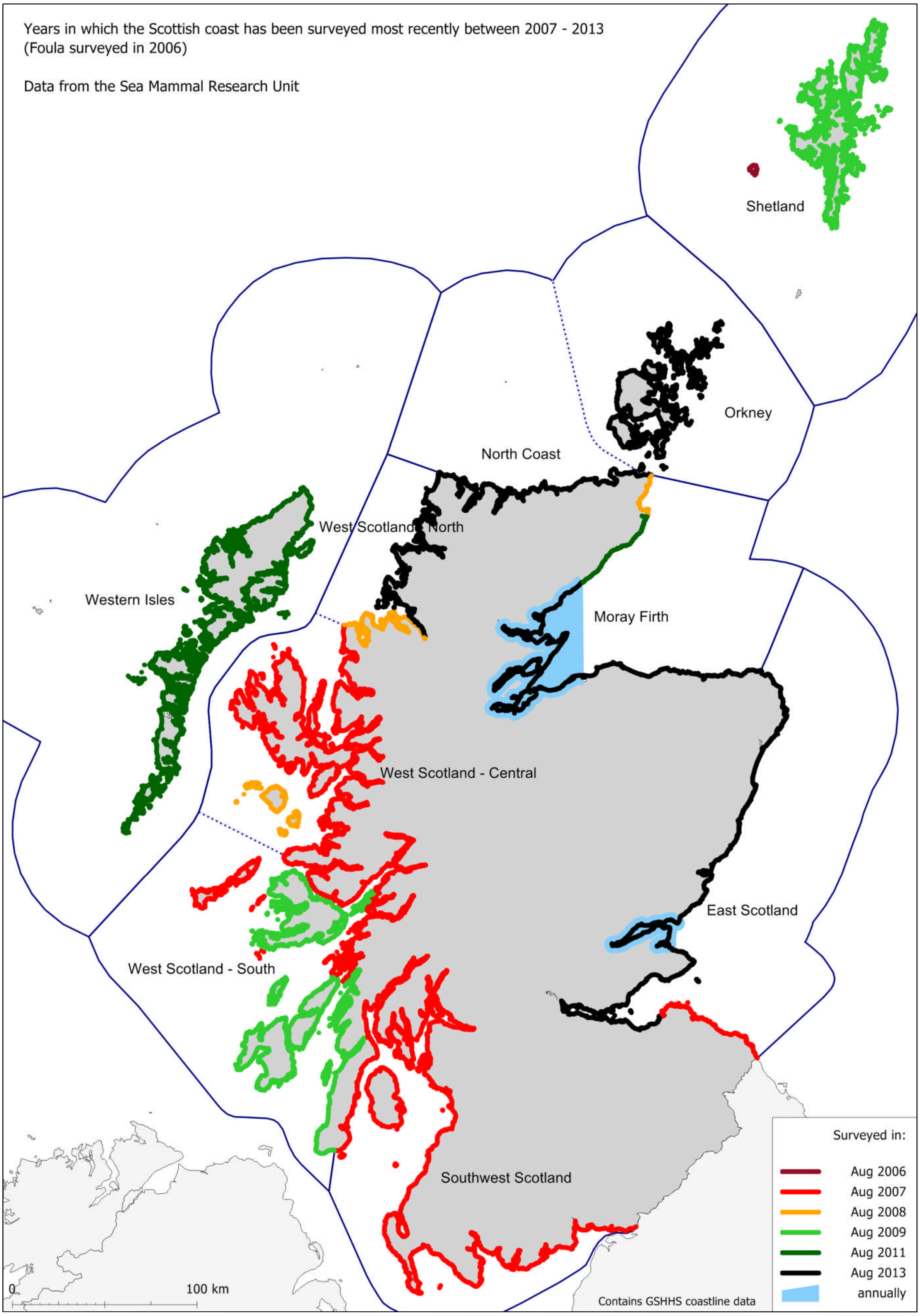

Figure 3. **Years in which different parts of Scotland were surveyed most recently by helicopter using a thermal imaging camera.** Most areas were surveyed between 2007 and 2013. Foula, off Shetland, was last surveyed in 2006. The enclosed areas of the Firth of Tay and the Moray Firth (between Findhorn and Helmsdale) are surveyed every year, usually by fixed-wing aircraft.

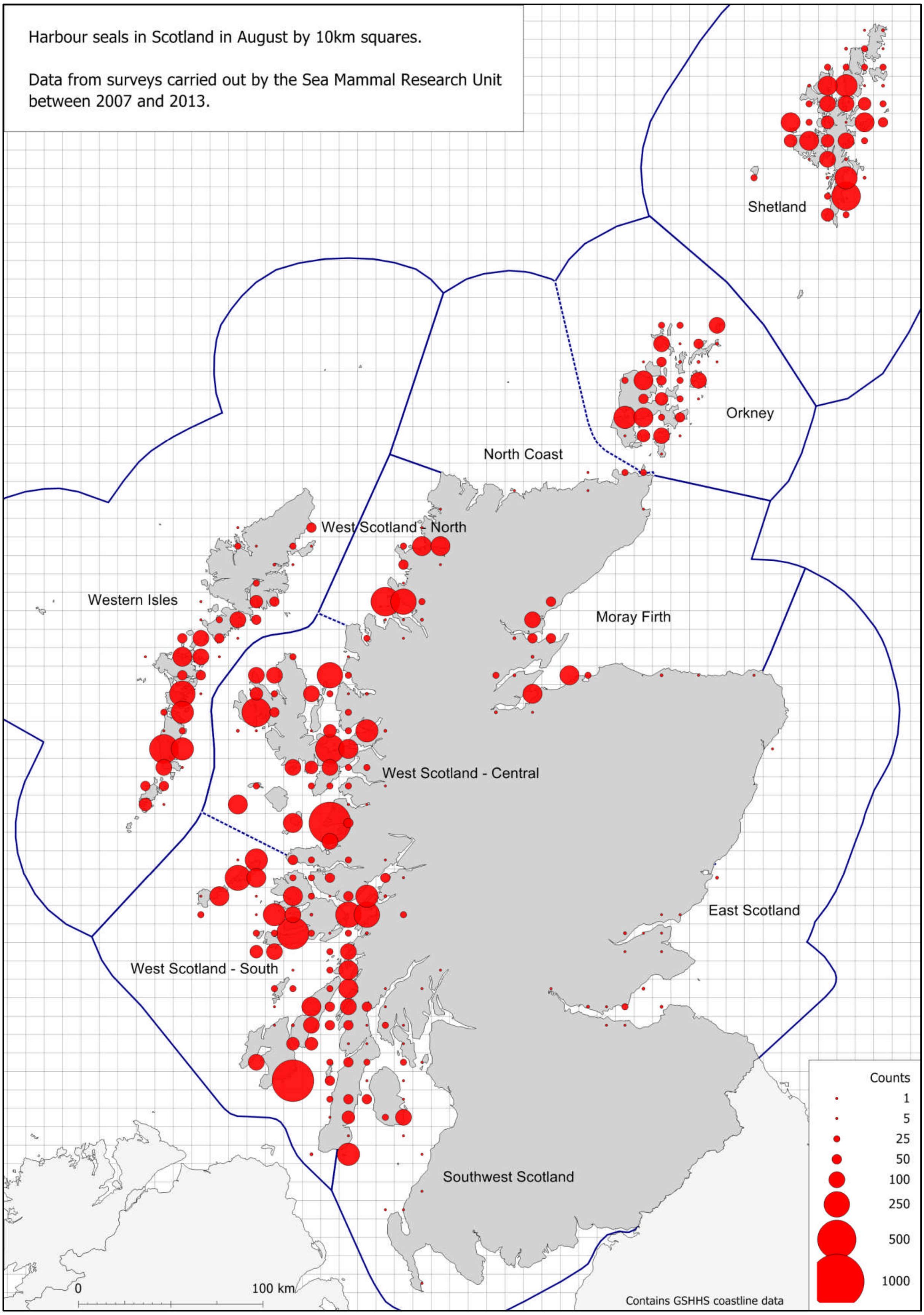

Figure 4. August distribution of harbour seals in Scotland. All areas were surveyed by helicopter using a thermal imaging camera, except for the Moray Firth area between Helmsdale and Findhorn, which was surveyed by fixed-wing aircraft without a thermal imager.

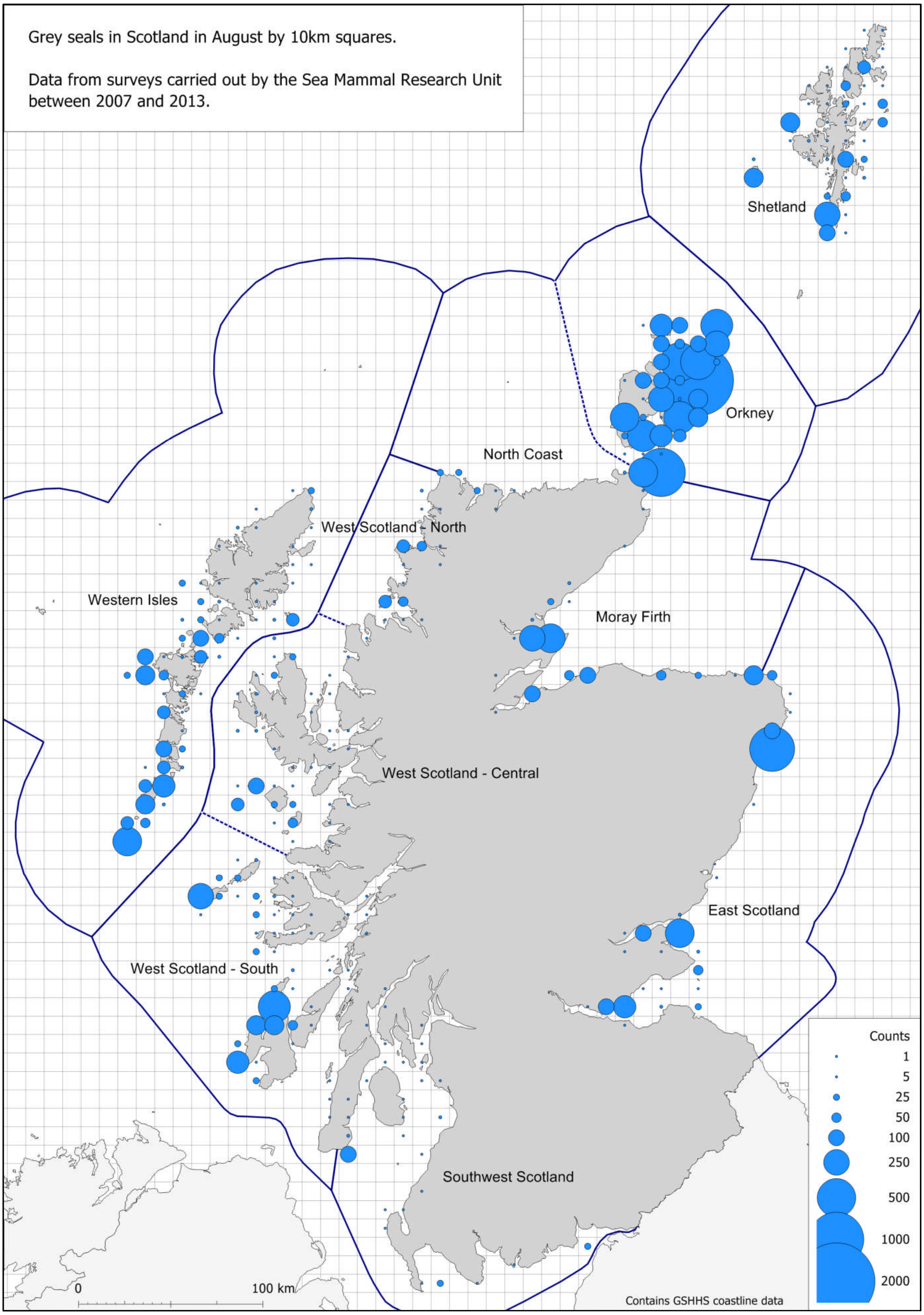

Figure 5. August distribution of harbour seals in Scotland. All areas were surveyed by helicopter using a thermal imaging camera, except for the Moray Firth area between Helmsdale and Findhorn, which was surveyed by fixed-wing aircraft without a thermal imager.

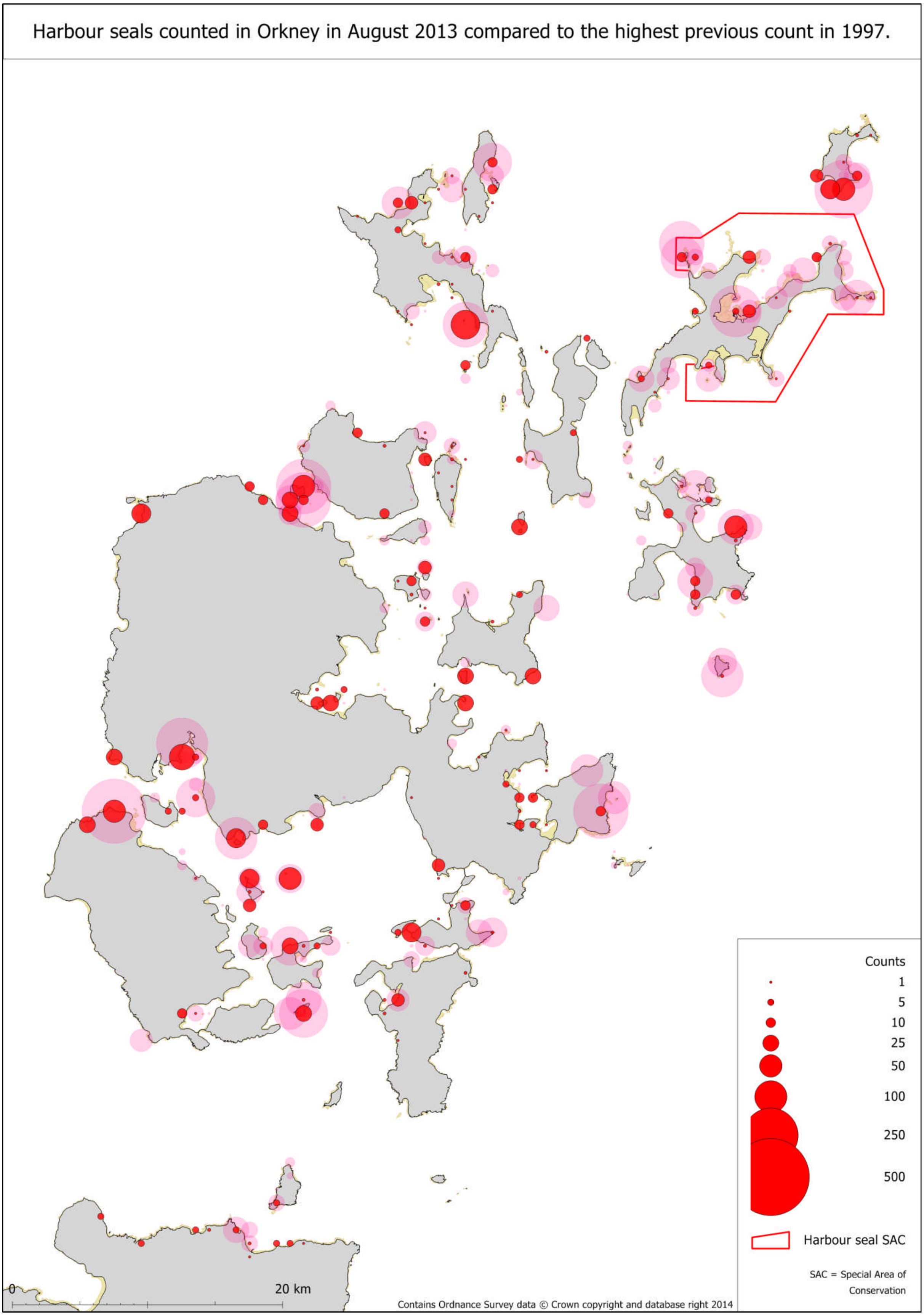

Figure 6. August distribution of harbour seals in Orkney in 2013 compared to 1997. Data have been aggregated by 1km squares to better display seal distribution. Data from the highest Orkney count in 1997 are shown in pink**.**

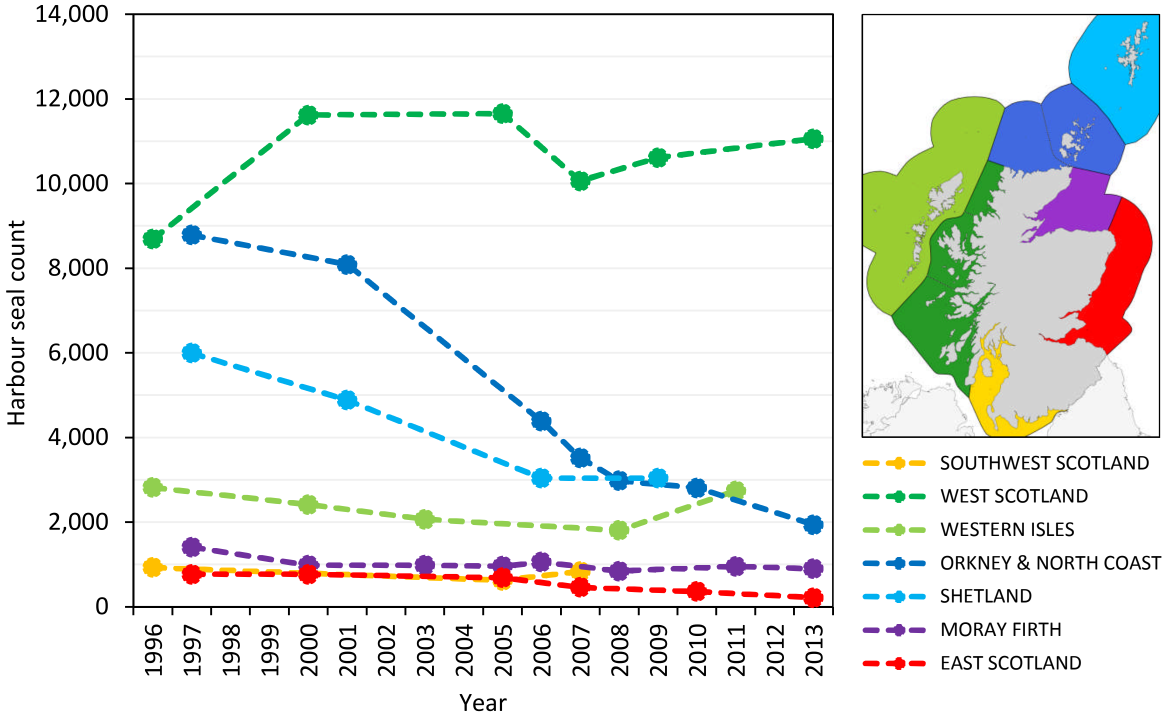

Figure 7. August counts of harbour seals in Scottish Seal Management Areas, 1996-2013. Data from the Sea Mammal Research Unit. Note that because these data points represent counts of harbour seals distributed over large areas, individual data points may not be from surveys from only one year. Points are only shown for years in which a significant part of the SMA was surveyed.

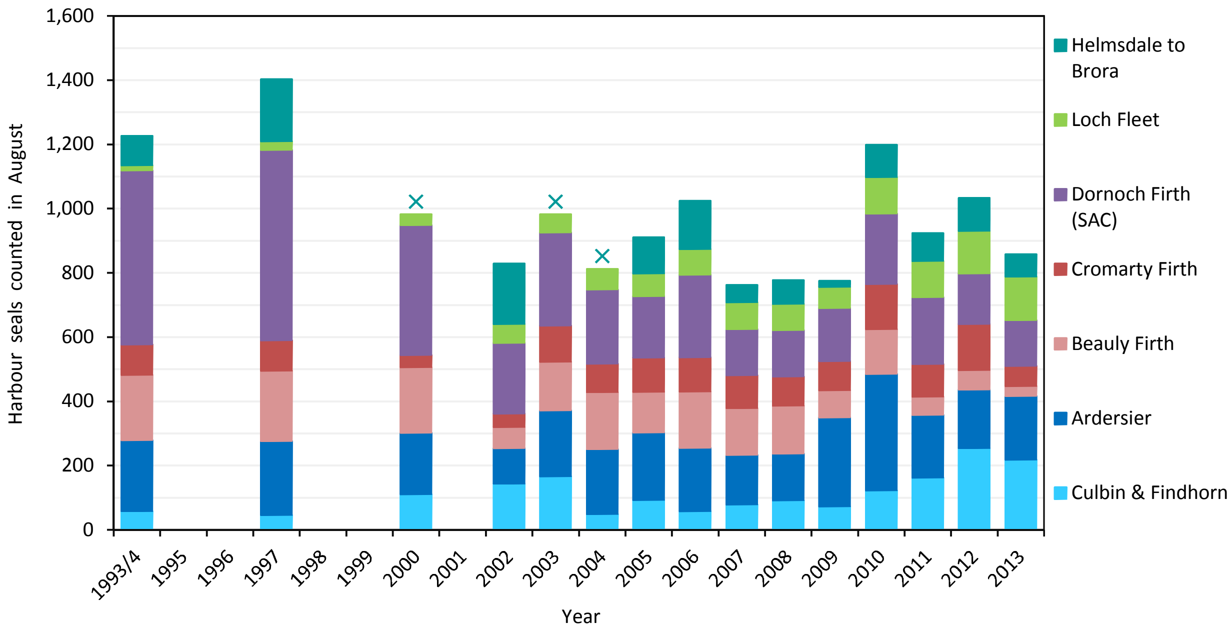

Figure 8. August counts of harbour seals in different areas of the Moray Firth, 1994-2013. Data are from the Sea Mammal Research Unit. X: Helmsdale to Brora not surveyed in 2000-2004.

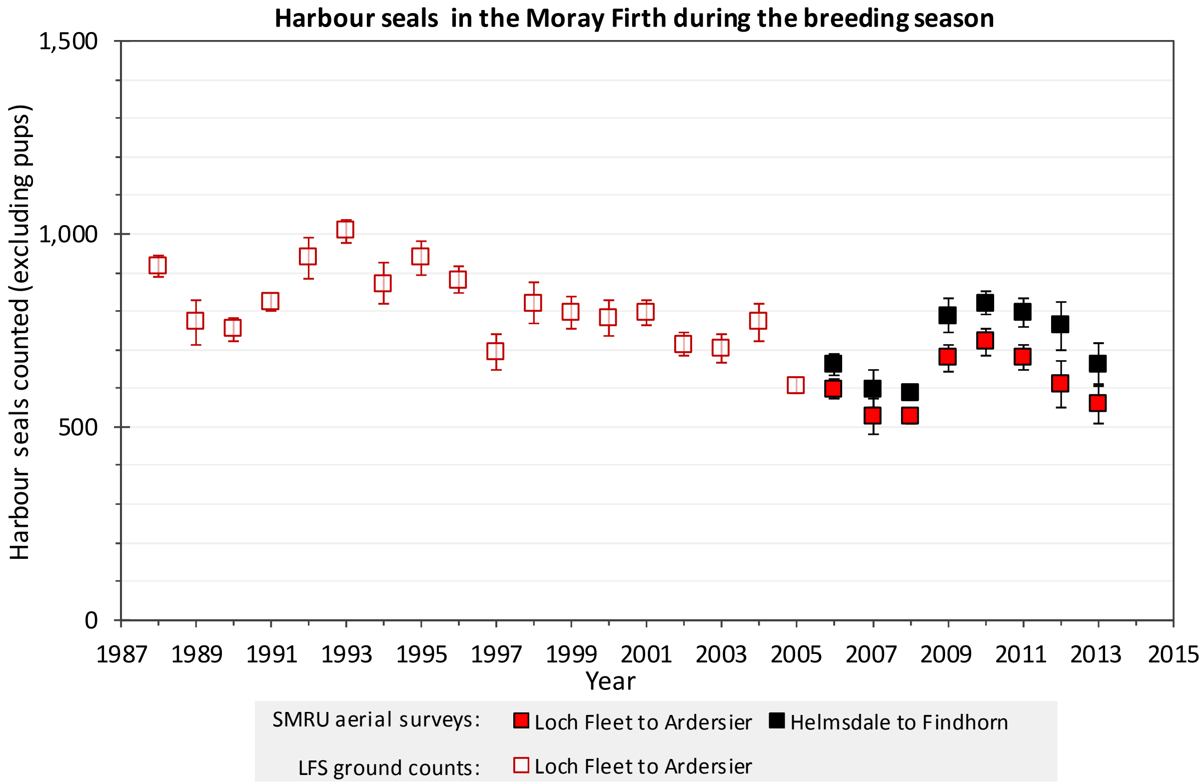

Figure 9. Counts of harbour seals in the Moray Firth during the breeding season (June & July), 1988-2013. Plotted values are means ±SE. LFS = Lighthouse Field Station (University of Aberdeen).

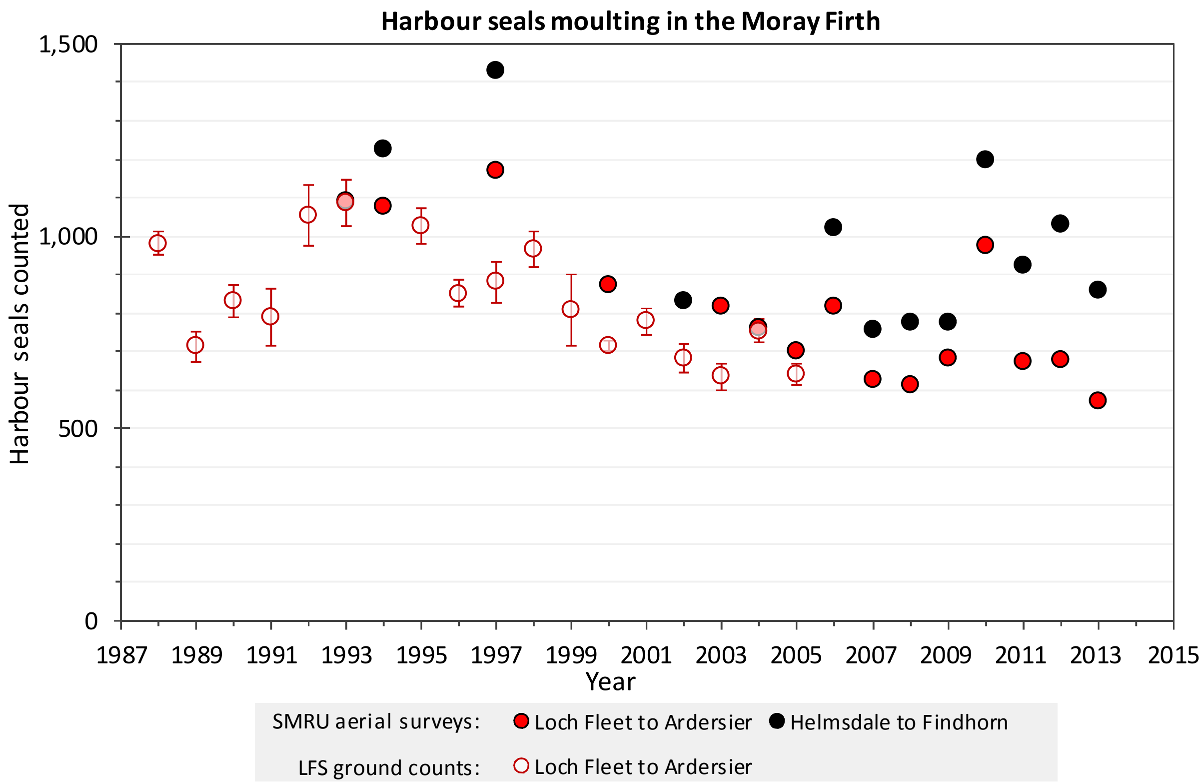

Figure 10. Counts of harbour seals in the Moray Firth during the moult season (August), 1988-2013. Plotted values are means ±SE where available. LFS = Lighthouse Field Station (University of Aberdeen). Detailed counts from moult surveys by the Sea Mammal Research Unit are in Figure 8.

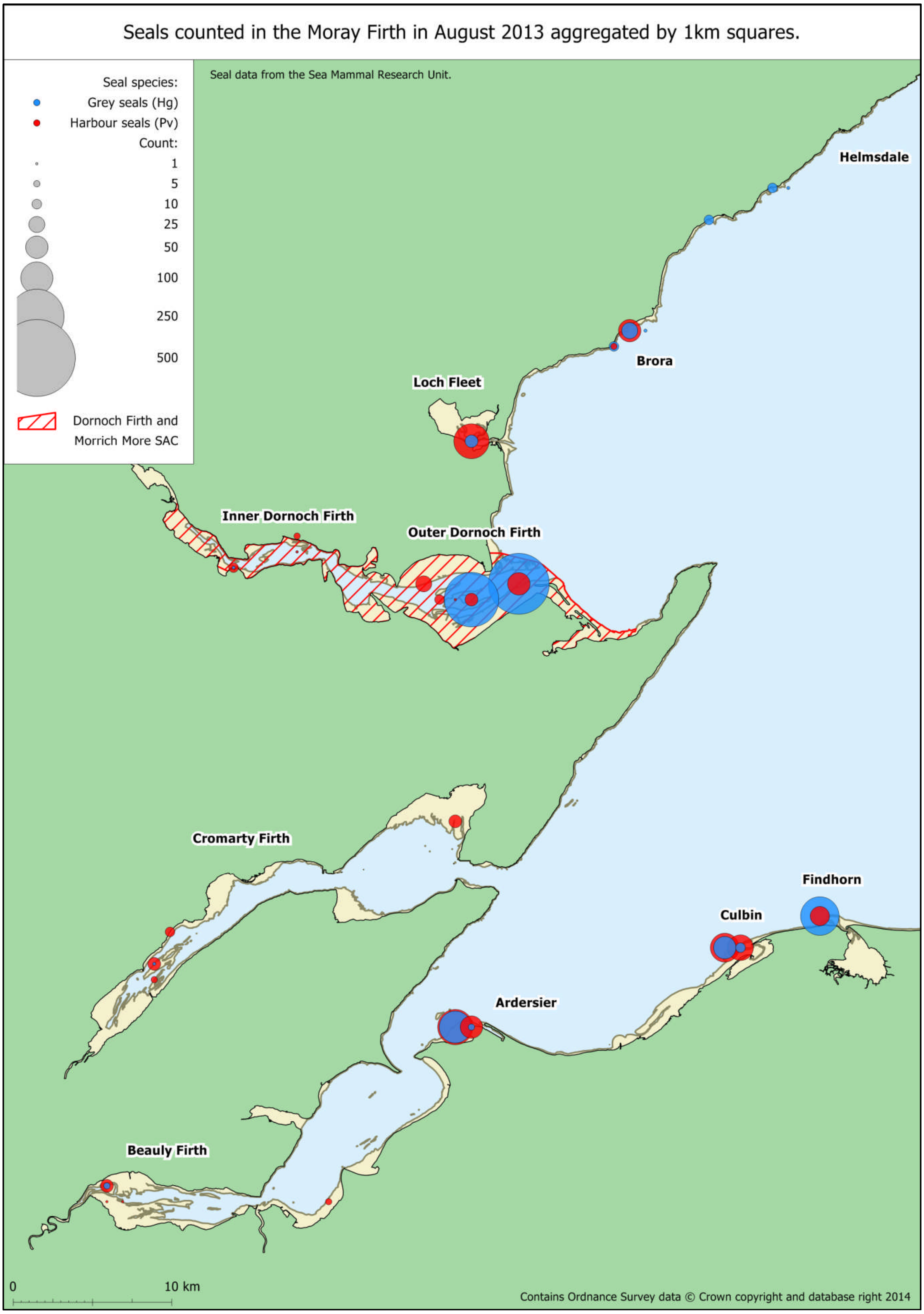

Figure 11. Distribution of harbour and grey seals in the annually surveyed part of the Moray Firth, between Findhorn and Helmsdale, from an aerial survey carried out by on 16th August 2013.

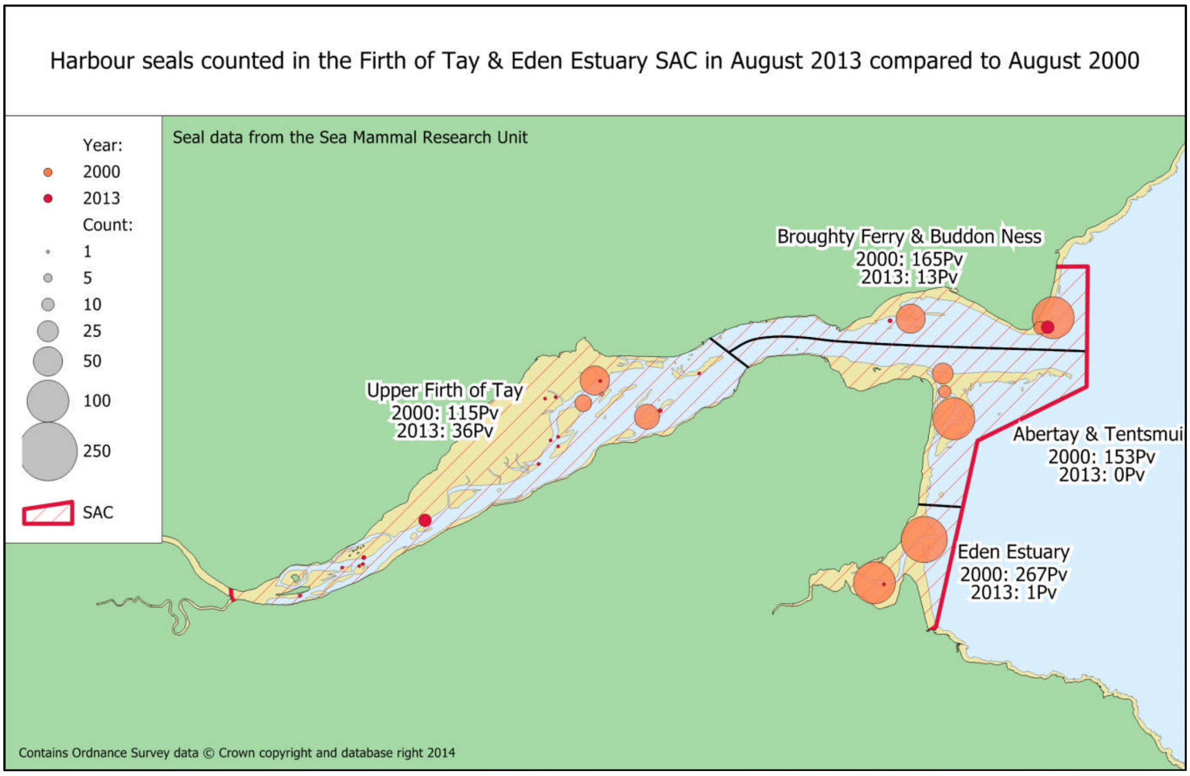

Figure 12. Distribution of harbour seals in the Firth of Tay & Eden Estuary SAC on 2nd August 2013 compared to 12th August 2000.

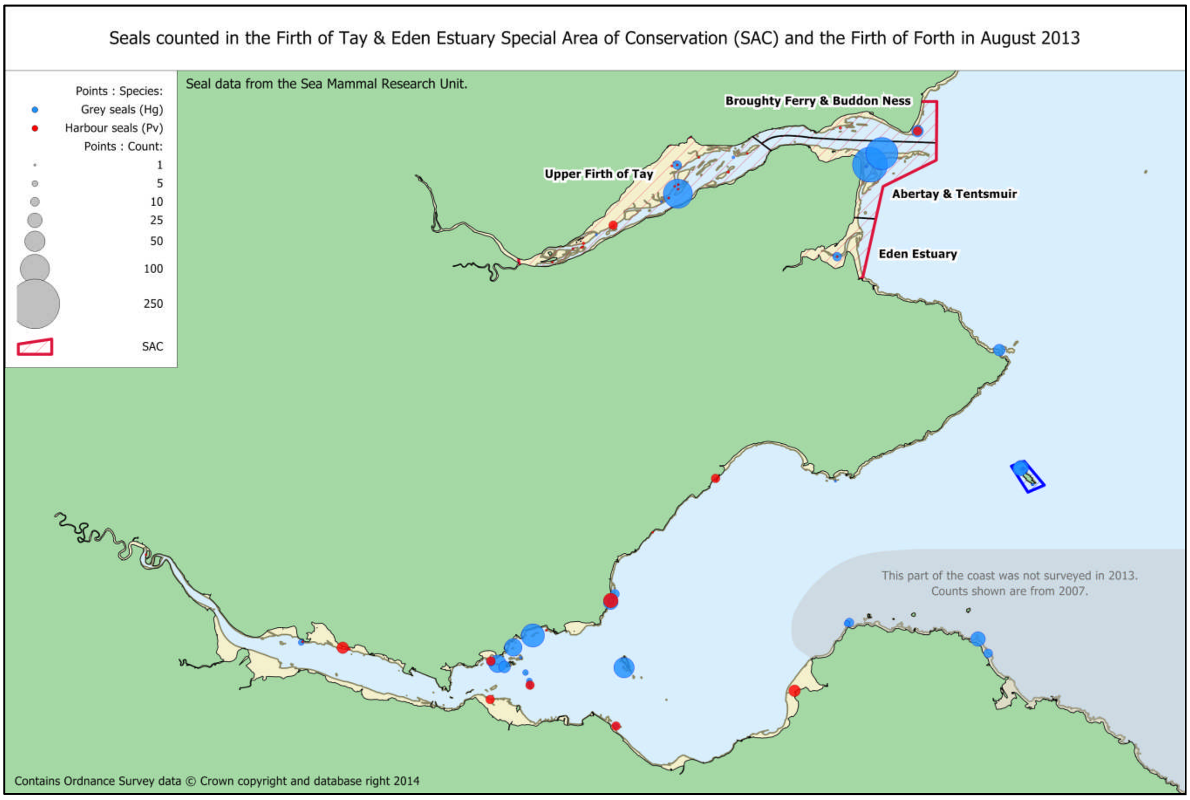

Figure 13. Distribution of harbour and grey seals in the Firth of Tay and the Firth of Forth in August 2013.

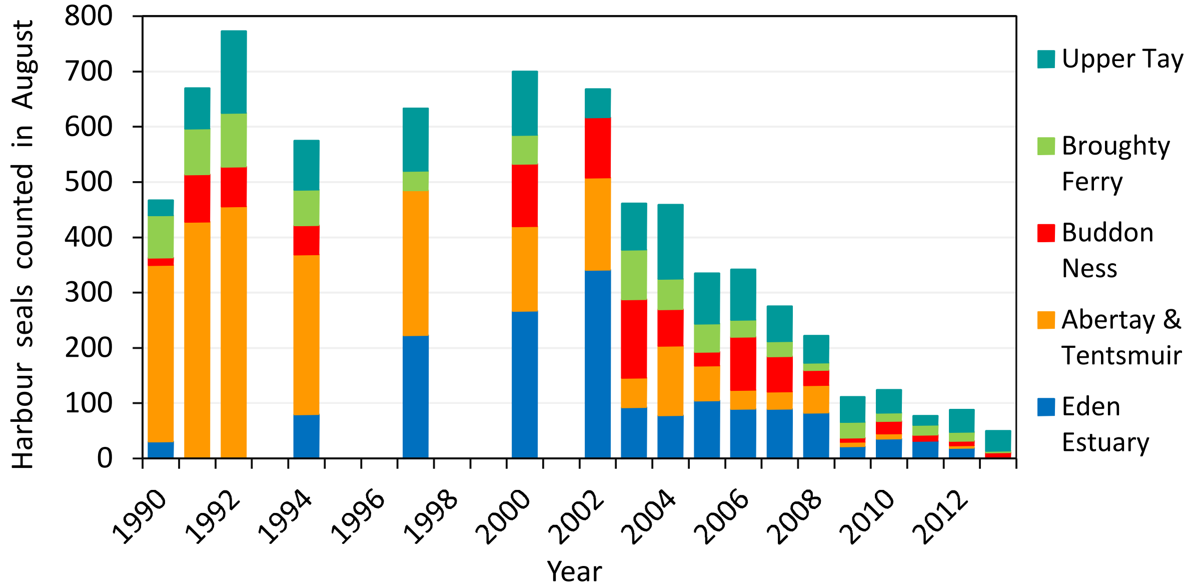

Figure 14. August counts of harbour seals in different areas of the Firth of Tay & Eden Estuary SAC, 1990-2013. Data are from the Sea Mammal Research Unit.

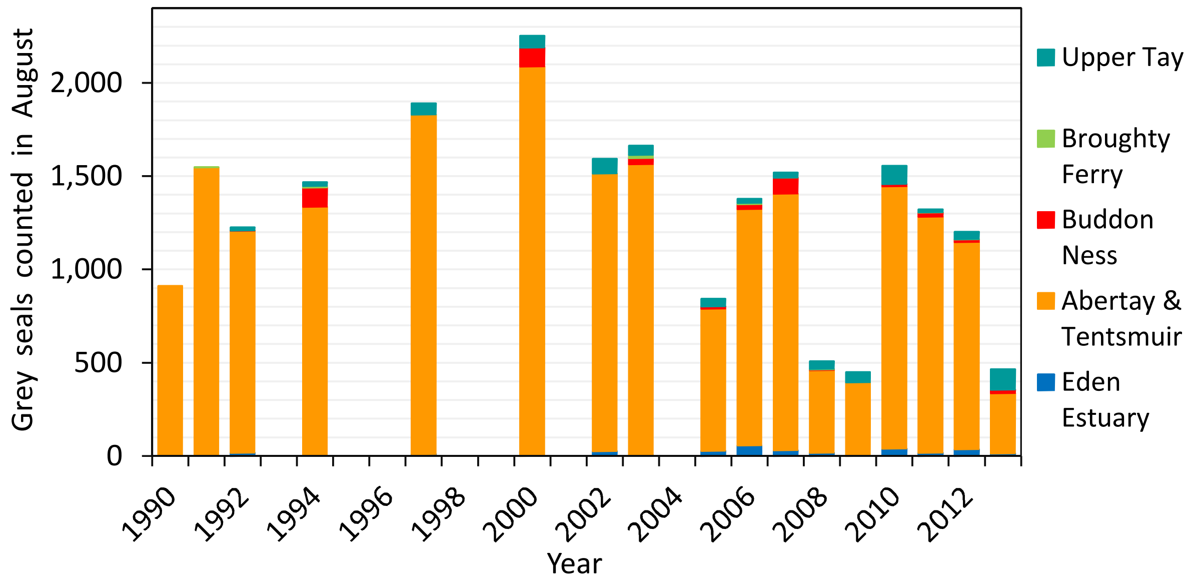

Figure 15. August counts of grey seals in different areas of the Firth of Tay & Eden Estuary SAC, 1990-2013. Data are from the Sea Mammal Research Unit.

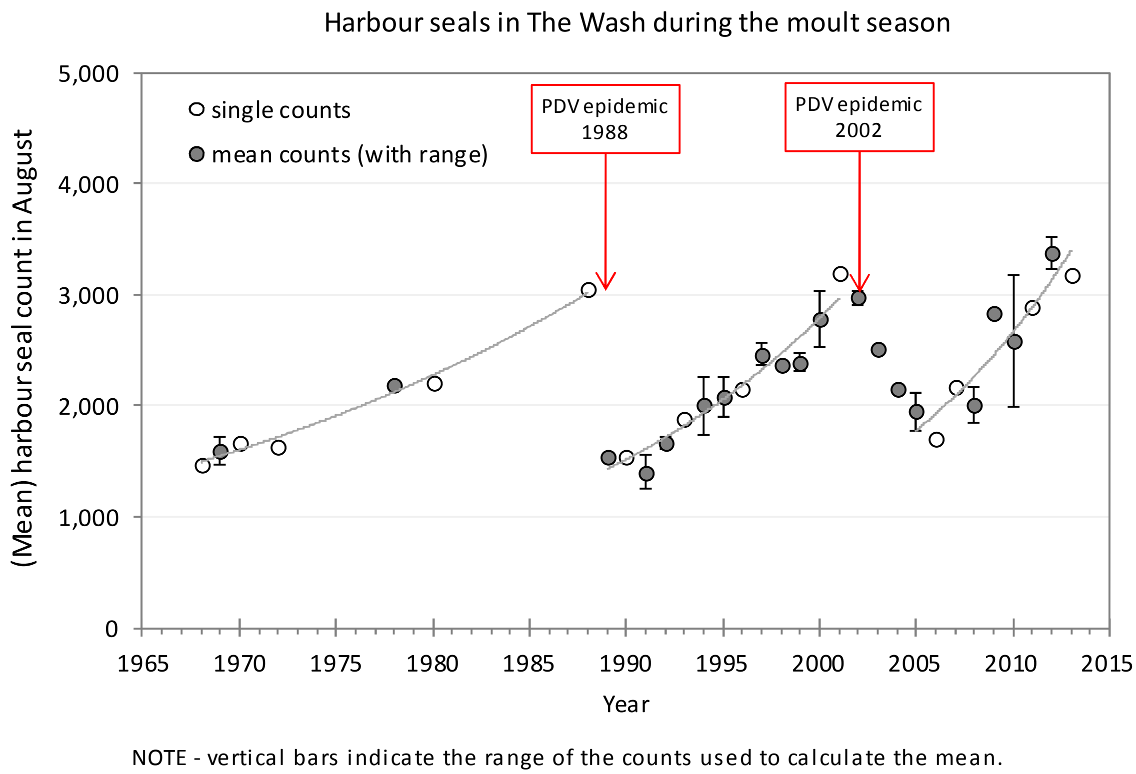

Figure 16. Counts of harbour seals during the August moult season in The Wash, 1967-2013. Vertical bars indicate the range of the counts used to calculate the mean (where more than one survey was carried out).

Colony specific implications of individual mass changes for survival and fecundity in female grey seals (*Halichoerus grypus).*

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Abstract

We present the results of a hidden process model fitted to long-term observational data from mark-recapture studies at grey seal breeding colonies on the Isle of May (IM) and North Rona (NR). We assume that mass changes between years are dependent on environmental factors and on the breeding status of animals, and explore the influence of an individual's mass on apparent survival, and fecundity. There was general annual variation in mass gain, especially at IM, presumably due to fluctuating resource availability. We find that females whose mass is low are less likely to breed, but that there is no strong evidence for a similar effect on survival. We are also able to arrive at general estimates of fecundity for females using each of these 2 colonies, including years in which they are not observed to attend the breeding colony. Overall fecundity estimates were different at the two colonies (0.770 NR, 0.860 IM).

Introduction

Fecundity is a key parameter needed to improve understanding of grey seal population dynamics at colony and larger spatial scales. However, it is difficult to estimate fecundity rates in a free-ranging marine mammal. UK grey seal fecundity has been estimated historically from ovaries obtained by lethal sampling on the Farne Islands and Outer Hebrides [1], but such estimates are subject to biases e.g they may fail to detect what proportion of early established pregnancies are actually brought to term. Also, the shot samples were collected during the early 1980s when the UK grey seal population was showing strong growth in pup production. Now it is clear that this growth has slowed or stopped in some areas at least [2]. Depending on how discrete the effective geographic breeding areas are, it is possible that life history parameters such as the age at which seals mature and the pattern of age-specific fecundity may have altered with time and area[3]. Simple estimates of apparent individual fecundity based on observations at North Rona (NR) and Isle of May (IM) breeding colonies are high, but are based only on those animals that attend the colony in a given year, potentially giving an inflated fecundity rate. Animals that are not breeding may be less likely to attend (or be re-sighted at) a breeding colony than breeding animals. Therefore, in order to obtain fecundity estimates that are relevant to population dynamics over multi-colony spatial scales, it is of considerable importance to consider the breeding status of seals that are not observed, and which may be absent from the colony.

We combine data on individual covariates – maternal mass and breeding status of individual seals for a given breeding season – with mark-recapture records (presence/absence of a female in a given year). We develop a Bayesian state-space framework to perform an integrated analysis of the data based on a simple CJS mark-recapture model. We assume that individual mass may change from year to year, dependent on the breeding status of animals, and explore the relationship between mass and the probability of breeding (individual fecundity). In years when an individual is not observed at the colony, its mass is unknown. Using observations of the masses of individuals before and after unobserved years, we impute the pupping status of unobserved animals and hence obtain overall estimates of fecundity for the grey seal populations breeding at the NR and IM colonies.

Methods

Data

For NR, re-sighting data from a total of 609 females were available covering the period 1987-2012. The objectives of the studies conducted and the marking methods used have changed over time. The animals in the data set included pelage-ID, tagged and branded animals. Some animals carried a combination of marks. Observers were not present at the colony during some years in the early part of the study (1983, 1984, 1990-1992). Initial exploratory investigation suggested that these 'skipped years' of observation pose some problems for the analysis of the observational data and we here report results based on analysis of the data from 1993 onwards. On the IM data (again from animals that were marked with varying combinations of brand, tag, and pelage-ID) were available for 258 individual females. Details of the mark-recapture protocols and the CJS model for the mark-recapture process including tag loss are reported elsewhere [4,5].

Analysis

We adopt a hidden process approach in which we model the underlying stochastic processes of survival, birth, and mass-gain which continue through the life of an animal (the 'process model'). We also take account of stochasticity involved in the observation process. The persistence or loss of marks is treated as a stochastic process, analogous to the survival of animals.

The underlying status of the animal i.e. whether it is alive or dead, pupping or not pupping, and marked or not marked, all influence the re-sighting probability of the animal. Therefore the underlying process model and observation model are intimately linked in this formulation.

Observation model

Fecundity rates of seals observed at the breeding colonies were consistently high: most females that were identified from pelage-ID, tags or brands went on to give birth. It is plausible that non-breeding seals are less likely to attend the colony than breeding seals, and because seals that are absent in a given breeding season cannot be observed, we anticipate that the re-sighting probabilities for breeding and non-breeding seals may differ. We therefore estimate separate parameters p_{pup} for the re-sighting probability of breeding females, and $p_{no\ pup}$ for the re-sighting probability of non-breeding females.

We also allow for the possibility that re-capture rate may depend on the type of mark or marks carried by an animal. The seals in the study set are marked with different methods and combinations of methods including photo-ID, branding, and flipper tags. The model allows that the combination of marks carried by an animal may influence the probability of observing it and estimates the re-sighting probabilities that correspond to different tag combinations[6].

Fitting the mark recapture data

We fit a hidden-process model. Mass change, survival, pupping and tag loss are stochastic processes that cause the state of an animal to change from one year to the next. Parameter values such as the tag loss rate, the relative effectiveness of marks, and the parameters of the logistic relationship between mass and fecundity, are estimated. Unknown states, e.g. whether an animal pups or not during a year in which it is not observed, are imputed.

Process model

We used a multi-state CJS model in which we allowed that (i) the probability that breeding and non-breeding animals attend the colony may differ (ii) animals seen for the first time may be 'transients' i.e. may belong to a particular group that is less likely to be re-sighted subsequently than animals that are not 'transients'[7,8]

We then allowed the probabilities both of breeding and survival to depend on individual mass. We expect that the mass of an individual female animal at the beginning of the breeding season in year *t+1* will be related to her mass at the end of the breeding season in year *t*, and that this relationship will depend on the pupping status of the female. The model is illustrated in Figure 1.

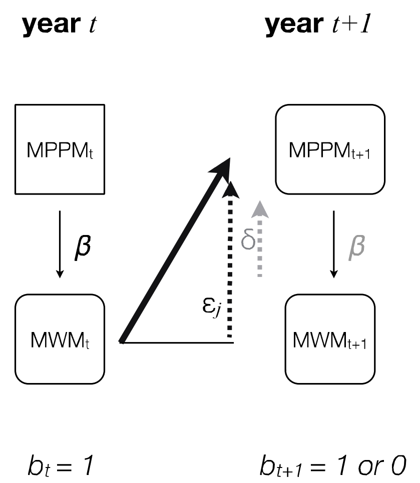


Figure 1: the mass at the end of breeding in year *t* is related to the mass at the beginning of lactation in year *t+1* by a general year effect ε_t and a further multiplier that depends on pregnancy state δ. During lactation in year *t+1* a breeding animal loses mass so that its mass at the end of lactation is β multiplied by $mppm_{t+1}$ Thus there is a net 'breeding effect' on mass represented by $\beta\delta$.

We parameterised a model for the way in which the mass of a female changes over time, and used this within the integrated analysis in order to estimate the effects of mass on survival and fecundity. We assumed a logistic relationship with a linear term to represent the relationship between mass and survival/fecundity. Preliminary investigations did not show any improvement to model performance when a polynomial relationship with a mass^2 term was included and because this caused numerical difficulties with long run times, the simpler form of relationship was chosen. The inclusion of animal age as an explanatory variable also caused numerical difficulties with model fitting (possibly because of colinearity with mass).

$f = exp(a_{pup} + b_{pup}mass)/(1+ exp(a_{pup}+b_{pup}mass))$

During the mcmc, the model also imputed the missing values of female mass (based on the processes shown in Figure 1) and pupping-status (based on the predictions of fecundity from the logistic model).

Results

Our parameter estimates are summarised in Table 1.

Parameter	Meaning	North Rona mean value and 95% Bayesian credible interval	Isle of May mean value and 95% Bayesian credible interval
β	Ratio of maternal mass at weaning to maternal mass at the start of lactation	0.644 (0.639, 0.650)	0.653 (0.648, 0.659)
δ	Ratio of maternal mass at the start of lactation to maternal mass at the end of lactation, in the previous year	1.44 (1.42, 1.46)	1.37 (1.34, 1.39)
$P_{transient}$	Probability that an animal recorded in the data set for the first time is a transient	0.161 (0.111, 0.209)	0.149 (0.0812, 0.221)
P_{pup}	Probability that an animal marked with a brand (i.e. highly visible) and pupping will be seen at the colony	0.875 (0.847, 0.902)	9.401 (9.184,9.616)
$P_{no\ pup}$	Probability that an animal marked with a brand which is not pupping will be seen at the colony	0.0834 (0.0633, 0.108)	0.0287 (0.0117, 0.0529_
a_{pup}	Parameter from the logistic equation for individual fecundity	-6.72 (-7.68, -5.77)	-10.6 (-13.1, -8.12)
b_{pup}	Parameter from the logistic equation for individual fecundity	0.0692 (0.0603, 0.0790)	0.117 (0.0922, 0.142)
a_s	Parameter from the logistic	2.90 (1.89, 3.98)	3.830 (2.14, 5.44)

	equation for individual survival		
b_s	Parameter from the logistic equation for individual survival	-0.00647 (-0.0139, 0.00118)	-8.92 (-2.07, 0.00489)
f	General estimate of fecundity for all animals at the colony, including years they are not observed at the colony	0.770 (0.750, 0.792)	0.860 (0.835, 0.882)

Table 1: parameter estimates (point estimates and 95% Bayesian credible intervals)

Mass change between breeding seasons

The variation in mass gain between years, *ε(j)*, is shown in Figure 2 for each breeding colony. Overlap between the 95% credible intervals suggests there are significant differences between years at NR and at IM. However, variation is more pronounced at the Isle of May

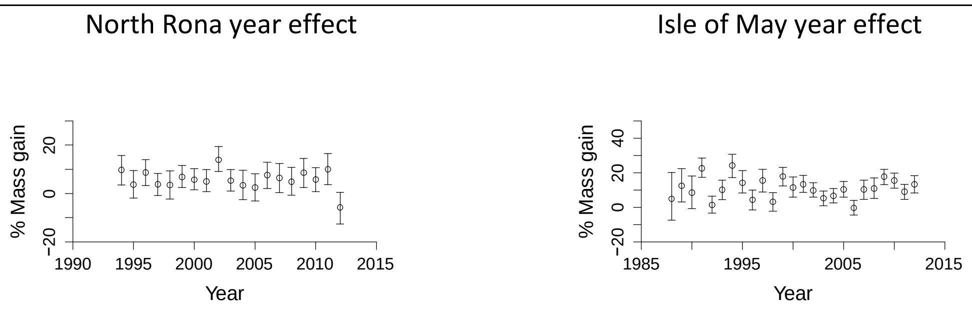


Figure 2: Annual variation in mass gain for 2 UK grey seal breeding colonies

Mass change during breeding season

For IM, the estimated value of *β* (the proportion of MPPM that remains after lactation costs) is to that at NR (see Table 1). Thus there appears to be no strong evidence for different expenditures at the study colonies. These estimates are consistent with the results of previous studies [6].

For IM the estimated value of *δ* (proportional difference in mass gain between pupping and non-pupping females) is smaller than for NR. In both cases, $\delta>1$ and this implies that animals breeding in year *t* in general have gained proportionally more mass between year *t-1* and year *t* than non-breeders. This effect appears to be stronger for NR animals (which in general are more massive than IM animals).

Tag loss

Tag loss rate estimates are comparable with estimates from previous double-tagging studies [3].

Survival

Figure 3 illustrates the predicted relationship at each colony between survival rate and mass. There is no evidence for an important effect at IOM, consistent with the posterior distribution of parameter b_s whose credible interval spans zero (see Table 1). At NR there appears to be stronger evidence for a negative relationship between mass and survival.

Survival-Mass relationship NR Survival-Mass relationship IM

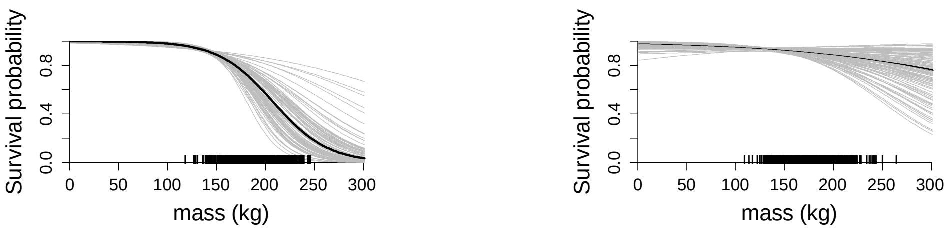


Figure 3: The relationship between survival and mass. In each panel the dark curve is based on the mean estimates of the logistic parameters, and the grey curves are simulations from random samples of the Markov chain. The rug plot indicates the range of the data at each site.

Fecundity

For both sites (see Table 1) there is evidence for a relationship between fecundity in year *j+1* and mass at the end of the breeding season in year *j*. This relationship between fecundity and mass is shown graphically in Figure 5.

Fecundity-Mass relationship NR Fecundity-Mass relationship IM

Figure 4: The relationship between fecundity and mass. In each panel the dark curve is based on the mean estimates of the logistic parameters, and the grey curves are simulations from random samples of the Markov chain. The rug plot indicates the range of the data at each site.

Overall fecundity estimates for the Isle of May and North Rona are lower than previous estimates for UK grey seals of of 0.94 for the Farne Islands, and 0.83 for the Hebrides (Boyd 1984). Fecundity at IM appears significantly higher than at NR.

Re-sighting: effect of pupping

At both colonies, the estimated probability of re-sighting a non-breeding female is low, consistent with the observation of few non-breeding adult females at these colonies.

Transience

At both NR and IM a small proportion of 'first seen' animals appear to be transients.

Discussion

Initial results show significant variation in mass gain between years for pupping seals, particularly at the Isle of May. This suggests that foraging success may vary between years due to environmental variation such as changes in the abundance and distribution of prey. It is known that the diet of UK grey seals varies in time and space and there is evidence that this corresponds to temporal and spatial variation in prey abundance [20-22]. Pup production also varies from year to year [8] and the condition and breeding success of other North Sea predators is also known to be variable [23, 24].

There is also some evidence that breeding incurs a small 'net cost' to animals. The product $\delta\beta$ represents the ratio between mass at the end of the breeding season in one year, to mass at the end of the breeding season in the preceeding year. Posterior estimates of this quantity are approximately 0.9 with 95% Bayesian credible intervals falling below 1. Thus animals may in some cases benefit by 'skipping' breeding in order to improve their general condition.

There is little indication of a clear relationship between mass and survival rate. This appears counter-intuitive: it might be expected that animals in poor condition, with low mass, would be more likely to die than those in good condition. This result may reflect that, in adult UK grey seals, the effects of any food shortage and poor body condition may be evident mainly through a failure by individuals to breed. Because non-breeders are far less likely to be seen at the colony than breeders, animals that have not been able to forage successfully would then be less likely to be seen at the colony. In attempting to fit a simple logistic model for the relationship between mass and survival, there may be a further difficulty if the effects of senescence are important for survival in older (and heavier) animals. Canadian grey seals show evidence of breeding senescence[9]. However, preliminary investigations with the current data set suggest that there may not be sufficient information in our data to distinguish any clear effect of mass and age on either survival or fecundity, and this may be (i) because the ages of some animals in the study are not known (where individuals are marked as adults, it is not known when they were born or when they first recruited to the colony) (ii) because colinearity between age and mass causes numerical difficulties.

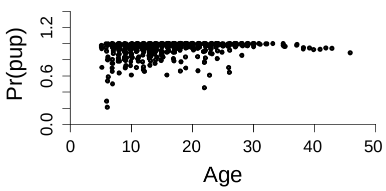
There is evidence of a positive relationship between maternal mass at the end of lactation and subsequent fecundity – a result that appears reasonable. Animals in poor condition may sacrifice breeding in order to assure their own survival. Younger, lighter animals may also be less fertile than older, heavier animals. Either of these processes is consistent with our model assumptions and our method for inferring general fecundity. However, if younger animals are more likely to breed elsewhere away from the colony, the estimated fecundity might be too low.

Many of the animals in the NR study set are not aged, but a more substantial proportion of the IM animals have associated age data. Using these, we generated a scatterplot (Figure 5) based on the fitted logistic relationship (equation 1) and on paired observations of age and mass (mppm) for individual animals *(i)* in particular years *(t)*

$$Pr(pup) = f(mass_{i,t}) \qquad (1)$$

$$mass_{i,t} \rightarrow age_{i,t}$$

Figure 5: relationship between estimated fecundity (from the fitted model) and the observed ages of study animals at IM



This plot does suggest that there could be an association between age and fecundity within our study set at least for IM animals - and the potential impact of this relationship on our fecundity estimates warrants further investigation.

Fecundity at NR appears to be somewhat lower than that at IM, and this seems consistent with lower survival and recruitment rates at NR compared with IM. There is also a general negative trend in pup production at NR and other Outer Hebrides colonies, while pup production at IM and other North Sea colonies continues to increase. 1980s estimates of pregnancy rates are considerably higher than the ones presented here for both the North Sea and Atlantic coast sites. Our lower figures for both colonies may result from a tendency for young animals to breed elsewhere that is not yet represented in our model or from a true reduction in pregnancy rates in these populations e.g. as a result of density-dependent changes in fecundity [3]. A competing explanation is that this difference is a reflection of the typical mammalian decline in the proportion of animals remaining pregnant, as pregnancy progresses. At present we do not have data to distinguish between these competing explanations.

Future objectives:

During data collection at the breeding colonies, continuing effort should be made to collect observations of any non-breeding adult females (this would assist in strengthening our estimates of associations between mass and breeding status).

Future telemetry studies might use longer-lived tags to follow animals through successive years. If so, one priority should be to explore the transitions made between breeding colonies by females of different ages.

Model structure should be investigated further e.g. using mass residuals or proportional changes in mass, rather than absolute mass, as a covariate.

It may be possible to develop modelling approaches to include individual correlates of survival/fecundity other than mass. Age would be of particular interest, and it may also be possible to include estimates of condition based on the analysis of labelled water or on photogrammetry.

To determine the value of including such covariates, it will be useful to develop more robust methods for model selection/comparison.

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Provisional Regional PBR values for Scottish seals in 2015

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Abstract

This document estimates Potential Biological Removal (PBR) values for the grey and harbour seal "populations" that haul out in each of the seven Seal Management Areas (and three subdivisions) in Scotland. Sets of possible values are tabulated for each area using the equation in Wade (1998) with different values of that equation's recovery factor. A value is suggested for this parameter in each population, the resulting PBR is highlighted, and a rationale is provided for each suggestion. The PBR values are calculated using the latest confirmed counts in each management area.

Changes since last year: The ongoing decline in harbour seals numbers in Orkney and the East Coast has reduced the PBRs in those areas. The increase in grey seal numbers in the Moray Firth is almost balanced by a reduction in Orkney.

Introduction

Potential Biological Removal is a widely used way of calculating whether current levels of anthropogenic mortality are consistent with reaching or exceeding a specific target population, chosen to be the Optimum Sustainable Population (OSP). It is explicitly given, in an amendment to the US Marine Mammal Protection Act, as the method to be used for assessing anthropogenic impacts in the waters around that country. The method has been supported by simulations demonstrating its performance under certain assumptions (Wade 1998). The PBR calculation is based on population size and intrinsic rate of increase and will therefore produce a PBR even for declining populations. The formulation includes a recovery factor (F_R) which can be altered to take account of population status. However, F_R only varies between 0.1 and 1 so the PBR method allows for small anthropogenic takes from any population, however much it is depleted or fast it is declining.

Scottish Government uses PBR to estimate permissible anthropogenic takes for each of the seven seal management regions and uses this information to assess licence applications for seal control and for other licensable marine activities.

Materials and Methods

The PBR calculation:

$$\mathbf{PBR = N_{min}.(R_{max}/2).F_R}$$

where:

PBR is a number of animals considered safely removable from the population.

$\mathbf{N_{min}}$ is a minimum population estimate (usually the 20th percentile of a distribution)

R_{max} is the population growth rate at low densities (by default set 0.12 for pinnipeds), this is halved to give an estimate of the growth rate at higher populations. This estimate should be conservative for most populations at their OSP.

F_R is a recovery factor, usually in the range 0.1 to 1. Low recovery factors give some protection from stochastic effects and overestimation of the other parameters. They also increase the expected equilibrium population size under the PBR.

The approach and calculation is discussed in detail in Wade (1998).

Data used in these calculations

N_{min} values used in these calculations are from the most recent summer surveys of each area, for both species:

- Harbour seals:

The surveys took place during the harbour seal moult, when the majority of this species will be hauled out, so the counts are used directly as values for N_{min}. (An alternative approach, closer to that suggested by Wade (1998), would be to rescale these counts into abundance estimates and take the 20th centile of the resulting distributions. Results of a recent telemetry study of harbour seal haul-out behaviour (Lonergan *et al*., 2012) indicate sex linked differences in haul-out patterns during the survey period. We do not have any information on the sex ratios of Scottish harbour seal populations, but the observed patterns suggest that the PBRs would decrease if the populations are predominantly female.)

- Grey seals:

Analysis of telemetry data from 107 grey seals tagged by SMRU between 1998 and 2007 shows that around 31% were hauled out during the survey windows (Lonergan *et al*., 2011a). The 20th centile of the distribution of multipliers from counts to abundances implied by that data is 2.56.

R_{max} is set at 0.12, the default value for pinnipeds, since very little information relevant to this parameter is available for Scottish seals. A lower value could be argued for, on the basis that the fastest recorded growth rate for the East Anglian harbour seal population has been below 10% (Lonergan et al. 2007), though that in the Wadden Sea has been consistently growing at slightly over 12% p.a. (Reijnders *et al*. 2010). Regional pup production estimates for the UK grey seal population have also had maximum growth rates in the range 5-10% p.a. (Lonergan et al. 2011b). However the large grey seal population at Sable Island in Canada has grown at nearly 13% p.a. (Bowen et al. 2003).

F_R needs to be chosen from the range [0.1, 1]. Estimated PBR values for the entire range of F_R values are presented. A recommended F_R value is indicated for each species in each region, together with a justification for the recommended value.

Areas used in the calculations

Figure 1 and Table 1 shows the boundaries of the Seal Management Areas.

Table 1: Boundaries of the Seal Management Areas in Scotland.

Seal	Management Area	Area covered
1	South-West Scotland	English border to Mull of Kintyre
2	West Scotland	Mull of Kintyre to Cape Wrath
3	Western Isles	Western Isles incl. St Kilda, Flannan Isles, North Rona
4	North Coast & Orkney	North Mainland coast & Orkney
5	Shetland	Shetland incl. Foula & Fair Isle
6	Moray Firth	Duncansby Head to Fraserburgh
7	East Coast	Fraserburgh to English border

Particularly for grey seals, there will probably be substantial movement of animals between these areas. The division is a pragmatic compromise that attempts to balance: current biological knowledge; distances between major haul-out sites; environmental conditions; the spatial structure of existing data; practical constraints on future data collection; and management requirements.

Results

PBR values for grey and harbour seals for each Seal Management Area. Recommended F_R values are highlighted in grey cells.

Table 2. Potential Biological Removal (PBR) values for harbour seals in Scotland by Seal Management Unit for the year 2015.

Seal Management Unit	2007-2013 count	Survey years	N_{min}	PBRs based on recovery factors F_R ranging from 0.1 to 1.0: 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	selected F_R	PBR
1 Southwest Scotland	834	(2007)	834	5	10	15	20	25	30	35	40	45	50	0.7	35
2 West Scotland	11,057	(2007-2009; 2013)	11,057	66	132	199	265	331	398	464	530	597	663	0.7	464
3 Western Isles	2,739	(2011)	2,739	16	32	49	65	82	98	115	131	147	164	0.5	82
4 North Coast & Orkney	1,938	(2013)	1,938	11	23	34	46	58	69	81	93	104	116	0.1	11
5 Shetland	3,039	(2009)	3,039	18	36	54	72	91	109	127	145	164	182	0.1	18
6 Moray Firth	898	(2008; 2011; 2013)	898	5	10	16	21	26	32	37	43	48	53	0.3	16
7 East Scotland	215	(2007; 2013)	215	1	2	3	5	6	7	9	10	11	12	0.1	1
SCOTLAND TOTAL	**20,720**	(2007-2009; 2011; 2013)	**20,720**	**122**	**245**	**370**	**494**	**619**	**743**	**868**	**992**	**1,116**	**1,240**		**627**

Table 3. Potential Biological Removal (PBR) values for grey seals in Scotland by Seal Management Unit for the year 2015.

Seal Management Unit	2007-2013 count	Survey years	N_{min}	PBRs based on recovery factors F_R ranging from 0.1 to 1.0: 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	selected F_R	PBR
1 Southwest Scotland	374	(2007)	957	5	11	17	22	28	34	40	45	51	57	1	57
2 West Scotland	2,700	(2007-2009; 2013)	6,912	41	82	124	165	207	248	290	331	373	414	1	414
3 Western Isles	2,518	(2011)	6,446	38	77	116	154	193	232	270	309	348	386	1	386
4 North Coast & Orkney	8,079	(2013)	20,682	124	248	372	496	620	744	868	992	1,116	1,240	1	1,240
5 Shetland	1,536	(2009)	3,932	23	47	70	94	117	141	165	188	212	235	1	235
6 Moray Firth	1,311	(2008; 2011; 2013)	3,356	20	40	60	80	100	120	140	161	181	201	1	201
7 East Scotland	1,935	(2007; 2013)	4,954	29	59	89	118	148	178	208	237	267	297	1	297
SCOTLAND TOTAL	**18,453**	(2007-2009; 2011; 2013)	**47,240**	**280**	**564**	**848**	**1,129**	**1,413**	**1,697**	**1,981**	**2,263**	**2,548**	**2,830**		**2,830**

Rationale for the suggested recovery factors

The original PBR methodology leaves the setting of the recovery factor as a subjective choice for managers. Factors such as the amount of information available about the population (and in particular its maximum annual growth rate), recent trends in local abundance, and the connections to neighbouring populations are relevant to setting this. The main factors affecting the value suggested for each species in each area are given below:

Harbour seals

1) Shetland, Orkney + North Coast and East Scotland ($F_R = 0.1$)

F_R set to minimum because populations are experiencing prolonged declines.

2) Outer Hebrides ($F_R = 0.5$)

Population was undergoing a protracted but gradual decline but the most recent count was close to the pre-decline numbers. The population is only partly closed being close to the relatively much larger population in the Western Scotland region, and the R_{max} parameter is derived from other seal populations.

4) Western Scotland ($F_R = 0.7$)

The population is largely closed, likely to have limited interchange with much smaller adjacent populations. The population is apparently stable and the intrinsic population growth rate is taken from other similar populations.

4) Southwest Scotland ($F_R = 0.7$)

The population is apparently stable, is closed to the south and the adjacent population to the north is apparently stable. The intrinsic population growth rate is taken from other similar populations.

5) Moray Firth ($F_R = 0.3$)

The recent counts for the Moray Firth show large inter annual fluctuations after a period of gradual decline. The higher counts in some years suggest that this population may be slowly recovering from the declines that occurred in the years around 2000. The neighbouring Orkney and Tay populations are continuing to undergo unexplained rapid and catastrophic declines in abundance. Data available from electronic telemetry tags suggest there is limited movement between these three areas. The PBR was set at 17 for 2013, permits for 16 harbour seals were granted and 3 were shot. We therefore, suggest that the F_R should be again set to a value of 0.3.

Grey seals

All regions ($F_R = 1.0$)

There has been sustained growth in the numbers of pups born in all areas over the last 30 years, with some now appearing to be at or close to their carrying capacities (Lonergan *et al*. 2011b). Available telemetry data and the differences in the regional patterns of pup production and summer haul-out counts (Lonergan *et al*. 2011a), also suggest substantial long-distance movements of individuals.

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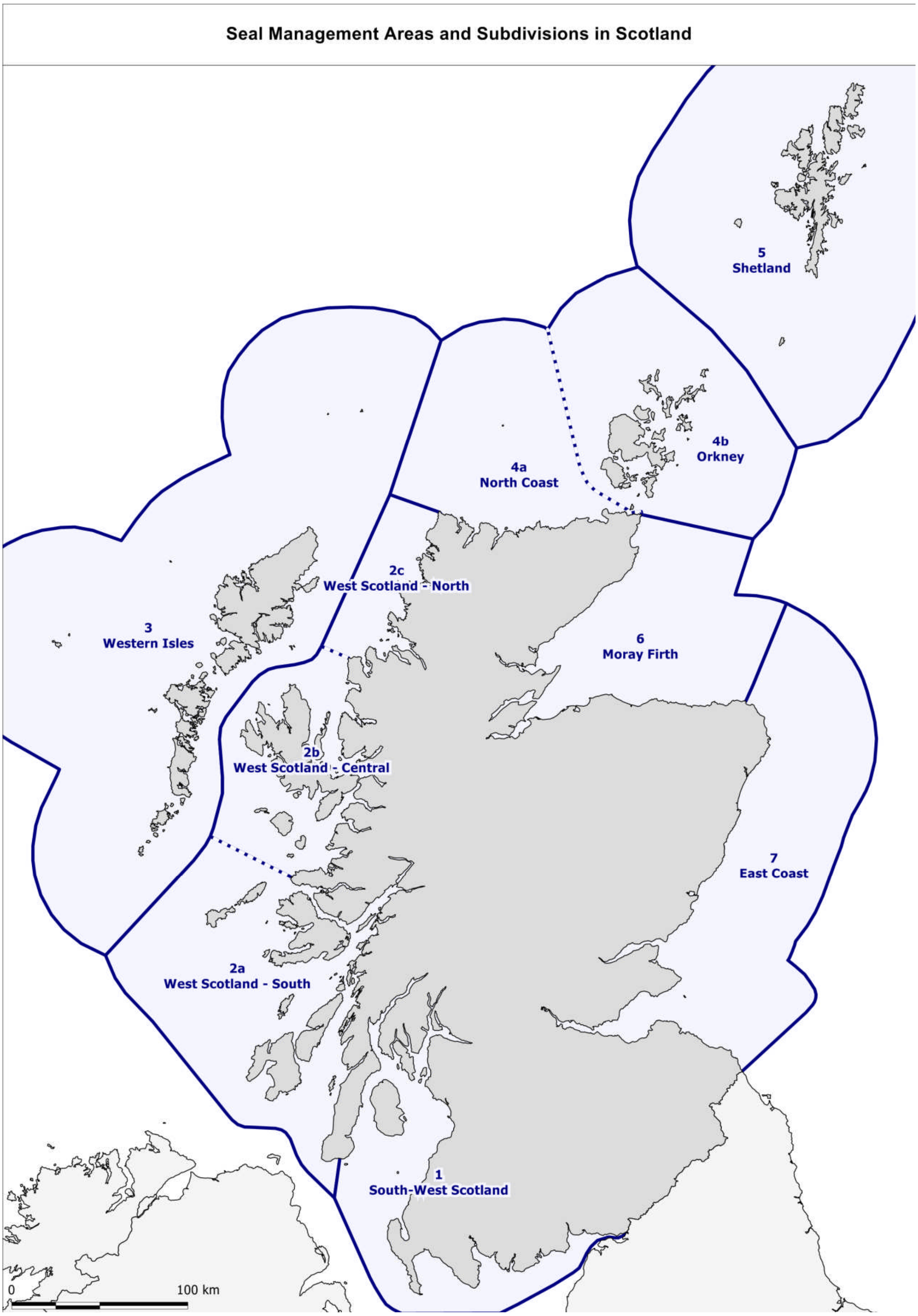
Figure 1. Seal management areas in Scotland.



Seal targets and indicators for determining Good Environmental Status under the Marine Strategy Framework Directive

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Abstract

Population data to support the UK and OSPAR common seal targets and indicators for determining 'Good Environmental Status' under the Marine Strategy Framework Directive continue to be collected by SMRU. Harbour seal abundance during the moult (indicator M3) and grey seal pup production estimates (indicator M5) are available, updated on an annual basis through SCOS and/or directly as requested from SMRU. Although the surveys for either species are not carried out annually, pup production estimates are available annually from 1956 to 2012 and biennially from 2012 onwards. Harbour seal moult counts are available for some areas annually and other regions more sparsely, as the aim of the synoptic thermal surveys is to cover the whole of the Scottish coast every five years. These abundance data are in a format that could be readily analysed in relation to any of the current targets that are being discussed. The UK distributional indicators for each species are still under development. However, data on the locations of the major grey seal breeding sites and the harbour seal moult haulout sites, whilst also readily available, are not currently reported to SCOS in a form that would be comparable to the targets. This would need to be the case to make these indicators fully operational at the UK level.

Introduction

The overarching goal of the Marine Strategy Framework Directive (MSFD) is for the European marine environment to achieve 'Good Environmental Status' (GES) by 2020. The Directive defines GES as "*The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive*". In order to accomplish this Member States are developing marine strategies to protect and conserve the marine environment within their relevant sub-regions, which for the UK are the Greater North Sea and the Celtic Seas. Since these strategies are being developed within each member state in some isolation, coordination is being managed through the Regional Seas Convention which for the UK is the OSPAR (Oslo and Paris) Convention (the Convention for the Protection of the Marine environment of the North-East Atlantic).

The marine strategies to be developed by each Member State must contain:

- *An initial assessment of the current environmental status of that Member State's marine waters;*
- *A determination of what Good Environmental Status means for those waters;*
- *Targets and indicators designed to show whether a Member State is achieving GES;*
- *A monitoring programme to measure progress towards GES;*
- *A programme of measures designed to achieve or maintain GES.*

Whilst the MSFD does not detail what comprises GES, a number of 'high-level' descriptors have been explained in Annex 1 of the legislation. The first of these is 'Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions'. It is under this 'Biodiversity' Descriptor 1 that a number of marine mammal targets and indicators have been established.

In the UK, HM Government published their 'Marine Strategy, Part One: UK Initial Assessment and Good Environmental Status' in December 2012 (HM Government, 2012). This is sets out the targets and indicators for GES within the UK and Devolved Administrations. In order to achieve GES in a coherent and strategic manner, the Directive establishes four European Marine Regions, based on geographical and environmental criteria. The North East Atlantic Marine Region is divided into four subregions, with UK waters lying in two of these (the Greater North Sea and the Celtic Seas). Each Member State is required to develop a marine strategy for their waters (EEZs or extended Continental Shelf areas), in coordination with other countries within the same marine region or subregion. This coordination is to be achieved through the Regional Seas Conventions, which for the UK is the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic (www.ospar.org).

To this end OSPAR's Joint Assessment and Monitoring Programme (JAMP) was revised in 2014 and will run until the next Quality Status Report is produced in 2021 (QSR21). The JAMP aims to align various strategic obligations towards improving the state of the marine environment, focussing on providing a framework and support for the requirements of MSFD as well as OSPAR. Of particular importance to the marine mammal targets and indicators mentioned above is that the JAMP will provide coordination under the MSFD resulting in a set of "Common Indicators" that will build on and replace the existing Ecological Quality Objectives (EcoQOs). OSPAR will produce an Intermediate Assessment of the Common Indicators in 2017 (IQSR17), which is intended to help Contracting Parties prepare for MSFD reporting in 2018 on their progress towards achieving GES.

Indicators

OSPAR's Intersessional Correspondence Groups on the MSFD (ICG-MSFD) and on the Coordination of Biodiversity Assessment and Monitoring (ICG-COBAM) have been developing a suite of common biodiversity indicators, including bespoke indicators for seals and cetaceans. OSPAR Contracting Parties in the Greater North Sea sub-region have adopted the following common indicators for seals (under GES Descriptor 1: Biodiversity):

M-3 Abundance of grey and harbour seals at breeding and haul-out sites, respectively

M-5 Grey seal pup production

Both indicators are also candidate indicators for the Celtic Seas sub-region, but require support from the Republic of Ireland before they can be adopted as a common indicator there.

The JNCC on behalf of the UK has agreed to lead on the development of indicators M3 and M5 in the North Sea and Celtic Seas.

The International Council for the Exploitation of the Seas (ICES) Working Group on Marine Mammal Ecology (ICES-WGMME) were asked at their 2014 meeting to provide 'technical and scientific advice on options for ways of setting targets for the OSPAR common MSFD indicators for marine mammals'. The resulting 2014 Report (ICES WGMME, 2014) provides a number of recommendations and those of relevance to the seal targets and indicators will be highlighted here.

Abundance of grey and harbour seals at breeding and haul-out sites (M-3) and grey seal pup production (M-5)

The parameters or metrics obtained for these indicators are counts of seals whilst they breed or moult on land. In the UK, grey seals, pups are counted at the major breeding sites by SMRU using photographic air survey methods (SCOS-BP 13/01). Four or five counts per colony are generated, spread across the autumn breeding season and these counts are converted into a total population size using a Bayesian state-space model (SCOS-BP 13/02). Due to limitations in NERC funding these counts are now carried out biennially but all major colonies are still counted. Some of the additional colonies in England are counted from the ground by various NGOs on an annual basis and these numbers, where available, are combined with the SMRU data. The surveys therefore generate estimates of grey seal pup production (M-5) that can be compared year on year. Annual and biennial estimates of pup production are available for the UK from 1956 to the present. This represents one of the most comprehensive population estimate datasets for any mammal in Europe.

These estimates of pup production can be used as a proxy for the size of the grey seal breeding population and could be used to generate indicator M3. The number of pups at a colony each year equates to the number of females that have successfully given birth. The counts do not, however, represent the total number of breeding males and animals of both sexes that have not bred.

The abundance of harbour seals has been monitored in the UK regularly since the first phocine distemper virus outbreak in 1988. A minimum population size is estimated from counts of seals hauled out during their annual moult in August when the largest proportion of the population is on land. However, the annual coverage of sites is spatially uneven. All sites in some regions are surveyed every year (largely the estuarine sandbank haul-outs on the east coast) but the strategy is to survey the entire coast of Scotland every 5 years. This is because at the rocky haul-out sites, used predominantly in Scotland, the harbour seals are so well camouflaged that they need to be counted using thermal imagery survey methods. The thermal images allow the warm seals hauled out to be accurately counted as the images are captured by a helicopter-mounted camera system. This synoptic survey pattern has been adopted since 1992 and in recent years in Scotland this work has been co-funded by Scottish Natural Heritage. Data on the abundance of harbour seals during the breeding season has also been collected from limited locations, such as the Wash and the Moray Firth but the time series and spatial coverage is too limited for these data to be used as an indicator of abundance across the UK.

Distributional range and pattern of grey and harbour seal breeding and haul-out sites.

This indicator had previously been put forward by ICG-COBAM as a candidate indicator 'M1'. But in Feb 2014, OSPAR's Biological Diversity Committee (BDC) recommended to OSPAR Contracting Parties that development of M1 should not be continued and they should not adopt it as a common indicator. However, the indicator is included in the UK Marine Strategy Part 1 (HM Government 2012).

The problem with the indicator is that it could be interpreted at the species level (which in harbour seals, for example, would be very wide; in the north-south direction they range from Northern Norway to the French coast) or at the meta-population / management unit (MU) level. In addition, setting a historic baseline for the distributional range of the species and indeed for the pattern of haul-out and breeding sites that would act the reference is not simple. For example, grey seals were already extinct from some of the North Sea as far back as the Middle Ages so choosing a suitable reference period and restoration "range" is fraught with difficulties given the change in land use and climate over time.

Presumably changes of interest would be focussed on range contraction rather than expansion in which case the current air survey methods used to determine abundance and distribution of both species in the UK (see section below for details) plus the additional reports from ground surveys would be sufficient for detecting a substantial change, particularly in breeding site usage within MU's. Identifying trends near the edge of the spatial distribution for both species would however be difficult and movement of animals between MUs (both temporary and permanent emigration) needs to be accounted for. Telemetry studies may provide more data on foraging range and haulout site usage but these data are limited in scope and by time. In order to avoid these problems inclusion of the term 'range' may be discontinued and the 'distributional pattern' aspect of this indicator incorporated into the abundance indicator, M-3. But since abundance and distribution of seals on land are closely linked, combining the two indicators at the OSPAR common indicator level would reduce the total number being used and would assist in ensuring a common approach used by all member states as the location of haulout and breeding colonies are routinely collected during the abundance surveys.

Certain areas of the UK coastline are not currently surveyed by air (for example, from Newhaven on the southeast coast of England, west to the Scottish border at Solway is not surveyed by air) as the low numbers of seals which breed or haulout in these regions does not justify the cost of the air surveys. Grey seal pup production in some areas, such as Cornwall and Wales are monitored by NGOs and Natural Resources, Wales so data is available. Thus, although small changes in site use into these regions may not be detected, it is likely that substantial changes would be identified. How changes in patterns of distribution, of either species would best be measured has yet to be determined. But methods similar to those used for the seabird indicators, such as % change in occupancy of 2 km by 2 km tetrads, and comparisons between the proportion of existing and new tetrads occupied between surveys, would be possible. This presence / absence approach could be preferable to a more complex approach using the numbers of animals in each grid as this, at least for harbour seals during the moult, could be highly variable on a daily basis. If numbers were to be used these would need to be linked to population size but confidence intervals could be generated so that comparisons between points in time might be possible.

The spatial scale at which this is carried out is likely to be important as the larger the area the less likely shifts in distribution would be detectable. However, a sensitivity analysis could be conducted to determine the impact of grid size. In addition, work being undertaken at SMRU on the transition rates of harbour seals between haulout sites will also be important to consider, since the connectivity between sites and regions and where animals choose to haulout on any particular day will also be variable and different between regions and substrates (rocky compared to sandbank haul outs). It is unlikely that density estimates by area would be useful as this again is affected by substrate, availability of haul out at low tide and inter-individual distances particularly between animals on the large sandbank haul outs. Some more work does therefore need to be carried out on this indicator (see operationalization section below).

Baselines

For changes in pup production and abundance to be functional as indicators and for target setting, baseline levels must be appropriately set. Some consideration has already been given to this issue (ICES-WGMME 2014) and the UK Marine Strategy Part 1 (HM Government, 2012) states that the "baselines for the marine mammal targets will be consistent with those used for the Habitats Directive (i.e. 1992 or the closest best estimate). Experts from across the North East Atlantic have acknowledged that 'although the most robust way to set baselines for marine mammals is based on historical data, these are not available at the appropriate spatial and temporal scale'". Thus, since historical abundance is not always known, and in any case may now be inappropriate given changes in land use and climate, more recent baselines are indeed likely to be more suitable (as are also used to assess Favourable Conservation Status (FCS) under the Habitats Directive). Similarly, anthropogenic pressures on seals may have decreased in more recent years as levels of shooting have been reduced, culling is no longer carried out and legislation to reduce disturbance at haulout sites has been introduced under the Marine (Scotland) 2010 Act. Therefore more recent baseline reference periods or levels may also reflect a more favourable status for these species than in the past.

Options include using the maximum count obtained over the last decade or some suitable time period as assessed by expert opinion. These baselines would have to be applied at the MU level, since survey coverage is uneven and trajectories vary widely by location and between species. For example, for the declining Scottish harbour seal population, where the baseline is set (i.e. before or after the decline) will greatly affect whether the species is considered to be at GES or not. And if baselines are related to population carrying capacity, set to a level where population growth rates and trajectories are levelling off, again that would be impossible for regions of continuing exponential increase (such as grey seal pup production in the North Sea) where there is no sign of abundance reaching an asymptote.

Targets

The final adoption of targets for the common indicators has yet to be agreed by OSPAR CPs. However, the GES targets for marine mammals in the UK Marine Strategy Part 1 (HM Government 2012) described for the population size targets (M-3 and M-5 above):

> *at the scale of the MSFD sub-regions abundance of seals is not decreasing as a result of human activity: in all of the indicators monitored, there should be no statistically significant decrease in abundance of marine mammals caused by human activities;*

and similarly for species distribution (distributional pattern):

> *at the scale of the MSFD sub-regions the distribution of seals is not contracting as result of human activities: in all of the indicators monitored there is no statistically significant contraction in the distribution of marine mammals caused by human activities.*

Although it might be difficult to determine the causes of any contraction in distribution, if human activities were demonstrated to be the cause of disturbance it would be possible to compare distribution patterns before and after mitigation measures were put in place. However, it is likely that a combination of factors may be driving population movements and site usage and disentangling natural from human induced impacts may be problematic.

As for the distributional pattern (and as mentioned above these are likely to be linked) it would be possible to compare trajectories before and after mitigation of human induced impacts that are affecting population dynamics through effects on reproduction and/or survival. An example would be the increased mortality due to trauma from vessels (so-called 'corkscrew' seals (Bexton et al. 2012)). If an effective mitigation method was found and introduced the subsequent effect of the mitigation on the abundance of seals could be monitored. This was also demonstrated in the introduction of the Moray Firth Seal Management Plan which reduced the shooting mortality resulting in a more stable harbour seal population in the area (Butler et al. 2008).

For the OSPAR common indicators, M3 and M5, a number of other target suggestions have been discussed. The ICG-COBAM (2012) proposed the use of the existing OSPAR EcoQOs. These use a current baseline of a five-year running mean and a direction / trend based target. The state that 'taking into account natural population dynamics and trends there should be no decline of ≥10% as represented by a five-year running mean or point estimates (separated by up to five years) within any of the subunits of the North Sea'. However ICES-WGMME (2014) pointed out, these were drawn up to alert contracting parties to perturbations, triggering research into the causes of change rather than management actions. This is in contrast to the targets outlined in the ICG-COBAM proposed common biodiversity indicators technical specifications which include a <u>restoration</u> objective –

> *Maintain populations in a healthy state, with no decrease in distribution / population size*[28] *with regard to the baseline (beyond natural variability) and restore populations, where deteriorated due to anthropogenic influences, to a healthy state.*

For the abundance indicator (M-3) the first part of this target may require a trend analysis to be carried out to determine if there has been a significant decrease with regard to the baseline. In addition, ICES-WGMME (2014) recommended that power analyses be conducted to assess the effectiveness of current or planned survey regimes relative to any trend targets. Thus, in order to

[28] The wording is the same for the distributional pattern M-1, abundance M-3 and grey seal pup production M-5 indicators.

determine what level of change it would be possible to detect in the harbour seal moult counts (by MU) and how these compare with the OPSAR EcoQOs and other targets discussed below, power analyses using the software TRENDS (Gerrodette 1993) was carried out.

The harbour seal moult counts for the UK are patchy and sparse for some locations whilst others have been monitored annually since the late 1980s. Table 1 shows the harbour seal moult counts by management region used in the power analysis. Repeat surveys carried out on the west coast (SCOS BP 05/07) resulted in a generic coefficient of variation (CV) of 15%. For each region, using the frequency and pattern of surveys carried out to date (from the first to the last complete survey), using an 80% power level and a 5% probability to detect a change, the minimal declining trend has been estimated (Table 2). A similar analysis was carried out (Table 3) with a 20% probability to detected a change.

Since the EcoQO guidelines are a 10% decline over 10 years, the power to detect this target is also listed. However, in some regions in certain years' only partial survey within the management units were carried out, largely due to weather conditions, equipment failures and funding constraints (Table 1). Abundance estimates for these were calculated using the new data for the sections completed and the exiting data for the sections not surveyed. Clearly this will affect the robustness of these estimates, depending on the proportion of the region surveyed. However, for the most part the sections not surveyed represent only a small proportion of the total management unit.

This exercise shows that it is not possible to detect a 10% decrease over 10 years with the power and precision suggested by the EcoQOs with the current survey regime. The annual surveys with a CV of 0.15 and a power of 0.8 give a minimal detectable rate of change of 2% per annum.

For the annual grey seal pup production surveys a CV of 0.105 is estimated from the state-space model (SCOS-BP 14/02) which results in a minimum detectable change of 12% over the 50 years of the study (with annual surveys until 2010). Over 10 years, surveying every 2 years, a minimum detectable change with 80% power would be 26%, which equates to 3% per annum.

If a five-year running mean is used instead of a change in point estimates this has its own difficulties as changes in means over the five year periods may be just under the target level at less than 10% but over time the population may still be declining. This is because the baseline is shifting with each subsequent 5 year period. As discussed by ICES-WGMME (2014) mortality events such as an epidemic may not trigger the EcoQO and longer term changes may be overlooked. They recommended switching to a three year running mean to overcome some of these issues.

Other targets to be considered include the guidelines used in the Habitats Directive where an annual decline of 1% or more during a 6-year reporting period is used as a threshold value, although for long lived species a period equivalent to 2 or 3 reporting rounds is considered acceptable. This is similar to the EcoQO and would be similarly difficult to detect with sufficient power.

The IUCN Red List criteria define a species as vulnerable when an 'observed, estimated, projected or suspected population size reduction of ≥30% over any ten year or three generation period, whichever is longer where the time period must include both the past and the future, AND where the reduction or its causes may not have ceased OR may not be understood OR may not be reversible' (IUCN, 2013). For both species of seal the generation time is between 14 and 15 years (Pacifici et al. 2013) which, for a reduction of 30% over this time, equates to approximately 2% per annum. The annual and biennial surveys for grey seal pup production and total population size would be sufficiently frequent to detect a trend of this magnitude.

An alternatively proposed target threshold (ICES WGMME 2014) is more than 25% below favourable reference population size. This would clearly be much more quantifiable with the current survey regime. However, as has been discussed earlier, the difficulty is in deciding what the favourable reference population size should be.

Operationalization

At present data on grey seal pup production by management unit is available through SCOS, both historically and currently. These data could be readily supplied in a format that could be quickly analysed for comparison with the targets discussed above. SMRU has already been involved in the development of the ICES seal database and SMRU could continue to supply the data through this portal if required. However, whilst it is hoped that the ICES seal database could provide a mechanism for this reporting, this has not yet been agreed. OSPAR will need to make a formal request to ICES for this to occur and that will only come after CP to OSPAR have agreed to it. Similarly, the counts of harbour and grey seals during the harbour seal moult are reported to SCOS by management unit, updated on an annual basis. Again these could be supplied in any format, either directly or through ICES, such that comparisons with targets would be straightforward. Some additional work on the distributional pattern indicator is required. However, if the data in form required was requested through SCOS this could be included in the annual advice provided by SMRU.

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Table 1. Harbour seal moult counts by UK management unit, 1996 to 2013. Numbers in bold are complete surveys for that year, in grey are partial surveys and in grey italics no survey was carried out in that year so the previous count was carried forward.

		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	Southwest Scotland	**929**	*929*	*929*	*929*	*929*	*929*	*929*	*929*	*929*	**623**	*623*	**834**	*834*	*834*	*834*	*834*	*834*	*834*
2	West Scotland		8,811	*8,811*	*8,811*	11,617	*11,617*	*11,617*	*11,617*	*11,617*	11,653	*11,653*	10,058	9,992	10,611	*10,611*	*10,611*	*10,611*	11,057
3	Western Isles	**2,820**	*2,820*	*2,820*	*2,820*	**2,413**	*2,413*	*2,413*	**2,067**	*2,067*	*2,067*	1,981	*1,981*	**1,804**	*1,804*	*1,804*	**2,739**	*2,739*	*2,739*
4	North Coast & Orkney		**8,787**	*8,787*	*8,787*	*8,787*	8,084	*8,084*	*8,084*	*8,084*	7,926	4,384	3,520	**2,979**	3,009	2,809	*2,809*	2,412	**1,938**
5	Shetland		**5,994**	*5,994*	*5,994*	*5,994*	**4,883**	*4,883*	*4,883*	*4,883*	*4,883*	**3,038**	*3,038*	*3,038*	**3,039**	*3,039*	*3,039*	*3,039*	*3,039*
6	Moray Firth		**1,409**	*1,409*	*1,409*	1,176	*1,176*	831	1,172	1,002	**915**	1,028	763	778	776	1,200	954	1,063	898
7	East Scotland		**764**	*764*	*764*	831	*831*	799	592	590	**660**	667	**447**	394	283	296	249	260	215
8	Northeast England		**54**	53	47	**68**	69	62	48	50	**67**	62	**50**	48	56	60	64	70	81
9	Southeast England	2,826	3,177	3,407	3,521	4,200	4,364	3,953	3,408	3,333	3,234	2,885	3,098	**3,161**	3,932	**3,686**	3,946	4,568	**4,504**
10	Northern Ireland							**1,267**	*1,267*	*1,267*	*1,267*	**1,176**	1,177	**1,101**	*1,101*	1,082	**948**	*948*	*948*

Table 2. Power analysis , with a significance level, α= 0.05, to detect declining trends in harbour seal moult counts of different magnitudes by management unit and pattern of complete or partial surveys shown in Table 1. Dashes mean insufficient recent surveys have been carried out.

			CV = 0.05	CV=0.15	CV=0.20	CV = 0.05	CV=0.15	CV=0.20
		Duration (y)	Minimum detectable decline over survey period power=0.8	Minimum detectable decline over survey period power=0.8	Minimum detectable decline over survey period power=0.8	Power minimal detectable decline 10% over 10 years[29]	Power minimal detectable decline 10% over 10 years	Power minimal detectable decline 10% over 10 years
1	Southwest Scotland	12	-0.47	-1.17	-1.52	-	-	-
2	West Scotland[30]	17	-0.17	-0.46	-0.58	0.39	0.12	0.10
3	Western Isles	16	-0.18	-0.49	-0.62	0.40	0.12	0.10
4	North Coast & Orkney	17	-0.14	-0.40	-0.51	0.56	0.15	0.12
5	Shetland	13	-0.24	-0.64	-0.8	-	-	-
6	Moray Firth	17	-0.12	-0.34	-0.44	0.60	0.16	0.12
7	East Scotland	17	-0.12	-0.34	-0.44	0.60	0.16	0.12
8	Northeast England	17	-0.12	-0.34	-0.44	0.60	0.16	0.12
9	Southeast England	18	-0.10	-0.28	-0.36	0.60	0.16	0.12
10	Northern Ireland	10	-0.18	-0.50	-0.63	0.38	0.12	0.10

[29] Taking the last 10 years of surveys as the period of interest

[30] No complete survey in any one year

Table 3. Power analysis, with a significance level, α= 0.2, to detect declining trends in harbour seal moult counts of different magnitudes by management unit and pattern of complete or partial surveys shown in Table 1. Dashes mean insufficient recent surveys have been carried out.

			CV = 0.05	CV=0.15	CV=0.20	CV = 0.05	CV=0.15	CV=0.20
		Duration (y)	Minimum detectable decline over survey period power=0.8	Minimum detectable decline over survey period power=0.8	Minimum detectable decline over survey period power=0.8	Power minimal detectable decline 10% over 10 years[31]	Power minimal detectable decline 10% over 10 years	Power minimal detectable decline 10% over 10 years
1	Southwest Scotland	12	-0.29	-1.05	-1.50	-	-	-
2	West Scotland[32]	17	-0.14	-0.46	-0.64	0.50	0.24	0.22
3	Western Isles	16	-0.15	-0.49	-0.68	0.46	0.23	0.22
4	North Coast & Orkney	17	-0.13	-0.40	-0.55	0.66	0.27	0.24
5	Shetland	13	-0.19	-0.62	-0.87	-	-	-
6	Moray Firth	17	-0.11	-0.34	-0.46	0.75	0.29	0.25
7	East Scotland	17	-0.11	-0.34	-0.46	0.75	0.29	0.25
8	Northeast England	17	-0.09	-0.28	-0.38	0.75	0.29	0.25
9	Southeast England	18	-0.09	-0.27	-0.37	0.75	0.29	0.25
10	Northern Ireland	10	-0.16	-0.53	-0.74	0.55	0.25	0.23

[31] Taking the last 10 years of surveys as the period of interest

[32] No complete survey in any one year