Natural England Commissioned Report NECR261

Special Area of Conservation Condition Monitoring: Grey seals (*Halichoerus grypus*) in the Isles of Scilly during the 2016 pupping season

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

The Isles of Scilly were designated a European Marine Site (Special Area of Conservation) in 1996, with grey seals (*Halichoerus grypus*) as a named feature. Reporting is required every six years and this site was last surveyed in 2010. Therefore Natural England commissioned this report to inform on the condition of the site.

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Natural England Commissioned Report (REDACTED)

Special Area of Conservation Condition Monitoring

Grey seals (*Halichoerus grypus*) in the Isles of Scilly during the 2016 pupping season

Sue Sayer and Matthew Witt

Cornwall Seal Group Research Trust and the University of Exeter.

February 2017

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We are grateful to everyone who assisted throughout the project.

Summary

Background

The Isles of Scilly were designated a European Marine Site (Special Area of Conservation) in 1996, with grey seals (*Halichoerus grypus*) as a named feature. The recommended minimum standard for monitoring grey seals under the common standards for monitoring designated sites (CSM) set out by the Joint Nature Conservation Committee (1988) is once every six years.

We report on surveys for grey seals conducted in 2016, building on efforts from 2010 (Sayer et al. 2010). Surveys were conducted throughout the grey seal reproductive ('pupping') season in 2016. Boat-based counts of seals were made across the Isles of Scilly archipelago, alongside landings on four islands thought to support appreciable pupping, where visual foot counts were undertaken.

Boat-based and island landing surveys in late November 2016 were accompanied by drone-based thermal infra-red surveys. These were undertaken to ascertain the value of these techniques in wildlife population census for grey seals on the remote and sometimes challenging to access islands.

Results

Boat and land based surveys were conducted at an interval of 21 ± 8 days from 27/09/2016 to 30/11/2016. Counts of grey seals during boat-based surveys ranged from 399 (Nov. end) to 565 seals (Oct.) During surveys, most seals (mean ± 1 s.d.) were observed in the SSSI areas of the Eastern Isles (282 ± 48), followed by the Western Rocks (108 ± 49), Island 11 (80 ± 31) and the Norrards (13 ± 10). Counts in 2016 (493 +/- 78) were stable compared to those in 2010 (507 +/- 177). The spatial distribution of age and sex classes of grey seals was heterogeneous with proportionally more males on Island 11 and the Eastern Isles and proportionally more adult females on the Western Rocks and Norrards. Most islands supported more adult female grey seals than adult males, with the exceptions of Island 11, Island 62 and Island 14.

From boat-based census, pups were observed on the following islands (descending order), Island 11 (n=29), Island 5 (n=3), Island 14 (n=1), Island 67 (n=1), Island 25 (n=1), Island 36 (n=1) and Island 31 by Samson (n=1). Pups on Island 67 and Island 36 were recorded retrospectively from photos following surveys.

Four islands, previously identified in 2010, were visited throughout the 2016 grey seal reproductive season (four surveys) to describe pupping seasonality and to estimate pup production. White coated pups were observed during land based counts on all four islands. Surveys in October 2016 resulted in the greatest number of pups being identified; this survey also identified the greatest number of pups aged one week or less.

Of the 192 unique live pups identified during island surveys most were found on Island 11 (n=149; 78%), followed by Island 5 (n=15, 8%), Island 31; (n=15, 8%), Island 24 (n=9, 5%), Island 14 (n=1), Island 67 (n=1), Island 25 (n=1) and Island 36 (n=1). Pups observed during boat and land-based surveys were distributed across the intertidal zone with some observed in the sea and others above the highest astronomical tide level.

Photo identification

During surveys nine different grey seals were re-identified from photo identification catalogues for southwest England and Wales (six females and three males). From ongoing photo identification activities across the southwest, 48 different seals (22 females and 26 males) from the Isles of Scilly have been identified elsewhere at sites ranging from Skomer in Pembrokeshire Marine SAC (n=2), St Austell Bay (n=1), North Cornwall (n=5) and North Devon (n=1). These seals functionally link the Isles of Scilly to at least 16 other sites across southwest England and Wales (Sayer, 2017; In preparation).

Conclusions

The peak month for grey seals counted in 2016 occurred earlier than in 2010 (Oct vs. Dec). In 2016, grey seals were more distributed to the east of the archipelago (as compared to 2010), when they were found more to the western extent of the Isles of Scilly.

Pup numbers in 2010 and 2016 on Island 24 (10 vs. 9), Island 5 (17 vs. 15) and Island 31 (12 vs. 15) were similar in magnitude, whilst Island 11 had an appreciable increase (46 vs. 149). Estimates of pup production for these islands increased from 89-134 in 2010 to 221-234 in 2016. The estimated duration of the pupping season in 2016 was shorter (100 days) than in 2010 (144 days). Increased pup production was not mirrored by the seal count data which was stable, indicating potential issues with recruitment into the population.

Recommendations

Condition monitoring predominantly focuses on pup production; however, we make the following additional recommendations to help develop a more coherent understanding of grey seals within the Isles of Scilly SAC and SSSIs.

Boat-based surveys should be conducted during the moulting season, data from this period would help to improve an assessment of the extent of moulting season and site use, one of the key assessment attributes for condition monitoring. Monthly seal counts, including drone technology, across the calendar year would help to characterise the spatial and temporal distribution of seals throughout the archipelago and enable further investigation into the issue of recruitment. Greater knowledge would be invaluable in an assessment of disturbance experienced by seals during the main summer tourist season; this would aid any future evidence-based management activities should they be required.

Intensive photo identification work is required during each of the three seal seasons (pupping, moulting and summer) to better understand how seals that use the Isles of Scilly SAC are linked to other European Marine Sites in the Celtic Sea region, including France, Ireland, Wales and England. Annual pupping surveys would establish intra- and inter-annual variation with greater confidence and help to establish site fidelity by breeding male and female seals, such surveys could incorporate more islands. Pup counts undertaken on a more frequent basis than once every six years would provide data with sufficient power to robustly detect trends in pup production (Sayer et al, 2011).

The importance of Island 11 SSSI to grey seals in Scilly should be recognised, the potential for this to happen formally by making grey seals a notified feature of this SSSI should be considered.

Contents

Location

The Isles of Scilly is an archipelago situated 28 miles (45 km) from Land's End at the southwest extent of England and it is the most southwestern region of the British mainland. The Isles of Scilly consists of over 200 low-lying granite islands and rocks.

The Isles of Scilly is nationally important for its rich biodiversity and unique natural environment, recognised through its designation as an Area of Outstanding Natural Beauty (AONB), a Conservation Area and a Heritage Coast. In addition, there are several nature conservation designations reflecting the importance of these features - 26 Sites of Special Scientific Interest (SSSI), many of which form part of the Isles of Scilly Special Protection Area (SPA), a Ramsar site for breeding seabirds, a marine Special Area of Conservation (SAC) and a Marine Conservation Zone (made up of 11 individual sites).

The three main areas providing habitat for grey seals are the Western Rocks, Northern Rocks (Norrards) and the Eastern Isles (**Figure 1**).

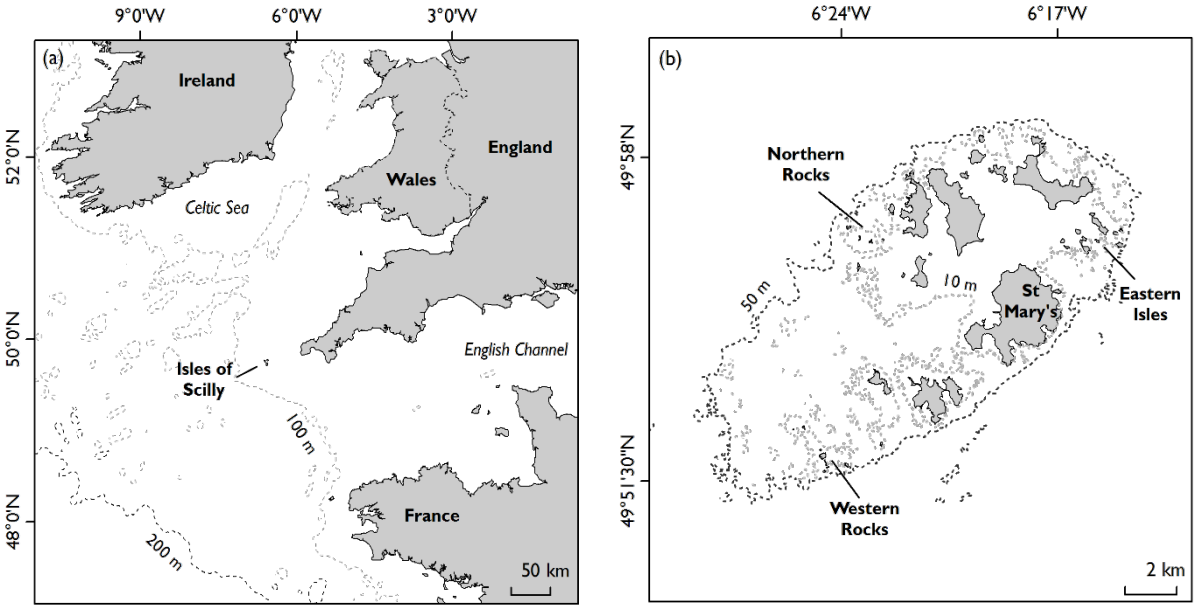

Figure 1. Geographic location of the Isles of Scilly (a) and three main seal areas (b).

Aims and objectives

In September 2016, Natural England (NE) contracted Cornwall Seal Group Research Trust (CSGRT) to undertake condition assessment monitoring of grey seals on the Isles of Scilly. The scope of the survey was agreed as four 2-day boat- and land-based surveys between September and December 2016.

Aims

Conduct a comprehensive wildlife census survey for grey seals, adopting protocols established in 2010 (NER0103). Trial unmanned aerial vehicle (drone) surveys for grey seals using optical and thermal-infrared techniques during select landing surveys. Drone surveys will enable an assessment of these technologies for wildlife population census while simultaneously providing an independent estimate of seals, not dependent upon direct counts by observers, but rather subsequent image analysis.

Objectives

Conduct a comprehensive survey of the grey seal population on the Isles of Scilly in 2016, to:

1. Identify and survey the sites where seal pups were born
2. Count the number of pups born
3. Follow the fate of individual pups for the duration of the survey period, as feasible
4. Obtain identification photographs of seals and to ensure the information is available for comparison with known individuals
5. Make low tide counts of seals in each island group, noting sex and age
6. Monitor levels of disturbance encountered, both at nursery sites (including by researchers) and at other seal haul-out sites in the archipelago
7. Analyse gathered data to establish numbers of pups, juveniles and adults, identify pupping and haul out sites and detail grey seal use of the different areas around the islands

The results from this monitoring activity will help inform site managers of any changes that may be required for the future management of the SAC. The surveys provide data to cover the full range of site monitoring attributes and will enable NE to make an assessment on the condition of this feature in the Isles of Scilly, as well as the site's contribution to conservation status more widely. Given grey seals can be subject to human disturbance the exact locations of seal observations and other data revealing specific locations have been redacted from this report.

Method

In 2010, Cornwall Seal Group (now Cornwall Seal Group Research Trust) was contracted by Natural England to conduct site condition monitoring for the Isles of Scilly (NER0103). A systematic survey route by boat around the archipelago was undertaken, covering the three main seal haulout areas (Western Rocks, Eastern Isles and Northern Rocks) and additional coastline. Landing surveys were conducted on four pupping islands (Island 11, Island 24, Island 5 and Island 31). This protocol was repeated in 2016 with an additional survey element involving an Unmanned Aerial Vehicle (UAV; drone) with optical and thermal infra-red camera technology.

Survey frequency

Counts of grey seal pups were to be conducted at 21-day intervals between September and late November, while showing regard to tides, daylight availability, to weather and sea conditions. Female grey seals give birth to a single white coated pup which they suckle for 17 to 23 days (SCOS 2009). Pups moult their white natal coat around the time of weaning (SCOS 2009). More frequent surveys to count pups would likely increase seal disturbance at this critical developmental stage. Less frequent surveys increase the complexity of calculating pup production estimates.

During the first survey, all white coated pups (2 to 3 weeks old) and fully moulted pups (most likely over 3 weeks old) were counted. During subsequent surveys at approx. 2-3 week intervals, all previously counted white coated pups were assumed to have fully moulted, so only white coated or partly moulted pups were added to the previous totals to provide a cumulative total of the number of unique pups encountered throughout the project. This approach could also be replicated for drone-based surveys when both video and thermal IR data are collected, video data can be used to validate which pups (and their thermal signatures) are white coated / partly moulted or not.

Survey planning

Permissions to undertake survey work were obtained from Natural England and the Isles of Scilly Wildlife Trust. Suitable days with low tides, during daylight hours, between September and November 2016 were identified as potential survey periods. Weather and sea conditions were monitored ahead of time for wind and swell conditions around St Martin's and St Mary's. When at least two days of calm weather were forecast, survey personnel were prepared, flights and accommodation booked, health and safety procedures initiated and survey equipment mobilised.

Boat-based counts

An experienced and licensed Isles of Scilly boatman with specialisms in both seals and the safe navigation of the shallow and complex waters of the Isles of Scilly was accompanied by at least two seal surveyors. This team followed a pre-determined route around the islands to undertake surveys. It is not possible to achieve full coverage of the entire Isles of Scilly coastline within a six hour window (three hours either side of low tide) over two days, so a route was devised to ensure coverage of all three main areas of seal haul out habitat around the Eastern Isles, Northern Rocks and Western Rocks, along with additional coastline as was feasible within the survey period. Boat survey routes were recorded using a Garmin GPSMAP 60CSx hand-held GPS device.

Where possible, boat surveys were conducted over two consecutive days. The boat moved at a maximum speed of five knots and at a slow, no wake speed when in proximity to seals. The boat remained at distance from the seals to minimise disturbance with only a subsequent, closer approach made once seals were acclimatised to the presence of the boat. Decisions were made prior to leaving St Mary's harbour about which survey areas were most suitable to visit on each day – usually based on the prevailing wind direction forecast. At each detection of a seal, the lead surveyor counted the total number of seals in and out of the sea, then aged and sexed them, counting juveniles first followed by adult sex, counting the dominant sex first. Where large numbers of seals were observed, photographs enabled retrospective counting, ageing and sexing of seals. To assist with data collection and in case of GPS failure, the Isles of Scilly were divided into 67 island sites each with a unique reference number (**Figure 2**). Additional information was also recorded where necessary, including the number of entangled seals and the number disturbed into the sea etc.

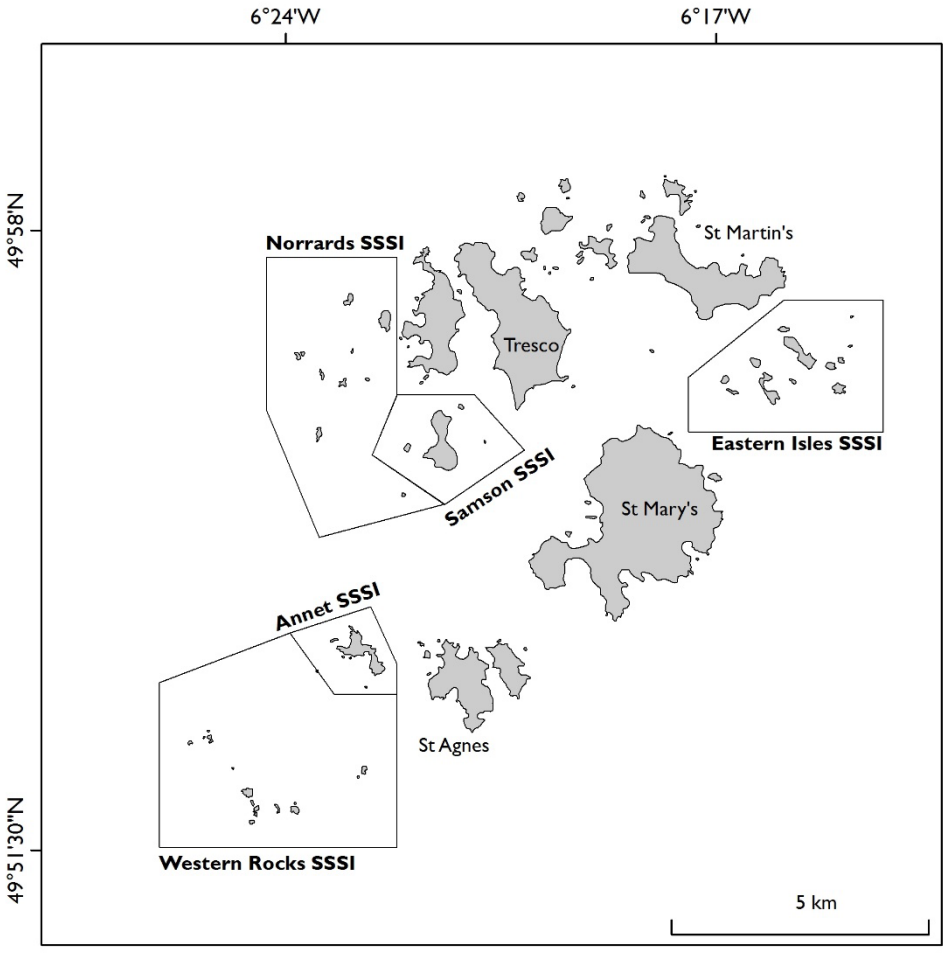

Figure 2. Map of Isles of Scilly showing SSSI areas.

Land-based counts

Land-based counts of pups were undertaken on four islands first surveyed in 2010; Island 11, Island 24, Island 5 and Island 31. A landing team comprised of a minimum of two surveyors. A suitable landing location was determined for each island according to local prevailing conditions. Landings on Island 5, Island 11 and Island 24 were most challenging. Island 11, being the largest of the islands, required 2-3 hours of survey time. Once a pup was identified it was allocated a sequential number and location (recorded by hand-held GPS). Each pup was assigned a code to describe its estimated developmental stage, based on Radford (1978) (**Figure 3**); photographs were taken wherever possible. Additionally, all seals encountered were assigned a second code reflecting approximate age in weeks by consolidating Radford's stages i.e. week 1 (stage 1), week 2 (stage 2) and week 3 (stages 3-5).

Figure 3. Development stages of grey seal pups.

Estimating pup production

A simple modelling approach was adopted to estimate the minimum production of grey seal pups from the four islands surveyed in 2016. First, a normal distribution was fitted through the survey-specific cumulative counts of pups. The extremities (tails) of this distribution were extrapolated until daily estimates of pup production were at least one pup per day. The estimated number of pups from this curve was subsequently divided by the approximate pup development duration (birth to fully moulted; e.g. 21 days). Given this period is variable, several estimates of total pup production were derived using weaning durations incrementally from 17 to 23 days. Final estimates of total pup production (median, 25th and 75th percentile) were derived from these seven estimates of production.

Unmanned Autonomous Vehicle with Thermal-IR

A drone-based thermal infra-red (IR) and optical video technique was used to improve the understanding of the distribution and abundance of grey seal pups in the Isles of Scilly. Previous efforts to quantify grey seal pups have involved landing on selected islands and undertaking visual surveys by foot. While this approach allows direct counts, it can cause disturbance and the lack of a high viewing angle can limit complete detection. Drone activity, survey design and fieldwork protocols were considered with respect to seabirds and flights only commenced once the survey teams had landed on each island and obtained permission to fly from the Isles of Scilly airport authorities. For each of two islands surveyed (Island 24 and Island 31), a drone-based (3D4 multirotor) thermal infra-red survey (FLIR; Tau620) followed by an optical camera (Rico) survey was conducted. Surveys followed pre-programmed flight paths with sensors orientated with a nadir (downward looking) configuration. Data were collected as streaming video on both FLIR and Ricoh cameras. Flight altitude was 75 m to minimise potential disturbance to seals. Surveys were attempted on 29th and 30th of November, although weather conditions (high winds) only permitted surveys on the second day of surveying. The drone survey team accessed islands by small row boat, the team established itself at a suitable vantage point on each island. Prior to each survey wind measurements were made using a hand-held cup anemometer. If wind gusts measured repeatedly over a 10-min period where below 15 mph then drone surveys were undertaken. Following surveys, the locations of seal pups identified by visual census from foot patrols and by drone were compared. This comparison would facilitate an estimation of detection probability for both techniques and aid an assessment of the drone survey's ability to discriminate differing stages of seal development using airborne video and thermal IR approaches.

Results

Survey effort

Four 2-day boat and land-based surveys were undertaken between September and November 2016 (**Table 1**).

Table 1. Surveys conducted for grey seals in the Isles of Scilly SAC.

Survey	Date	Areas surveyed	Landings	Beaufort force	Wind force	Wind direction
1	27/09/16	Western Rocks	Island 5, Island 11	5	4	SW
	28/09/16	Eastern Isles, Norrards	Island 24, Island 31	5	4	SW
2	14/10/16	Western Rocks	Island 5, Island 11	4	4	SE
	17/10/16	Eastern Isles, Norrards	Island 24, Island 31	4	4	W
3	13/11/16	Western Rocks	Island 5, Island 11	3	3	N
	14/11/16	Eastern Isles, Norrards	Island 24, Island 31	3	2	W
4	29/11/16	Western Rocks	Island 5, Island 11	3	4	E
	30/11/16	Eastern Isles, Norrards	Island 24, Island 31	5	4	E

The optimal survey interval, dictated by pup weaning duration, was 17 to 23 days. Achieving this optimum was challenging as only two suitable tide windows during daylight hours occurred each month. When factoring coincident weather conditions during September to November, which limited access to remote and exposed sites, the inter survey duration was 21 ± 8 days (min. 17; max. 30).

Boat-based surveys

Boat-based surveys achieved near complete coverage of the three main seal areas; including, Eastern Isles, the Northern Rocks and the Western Rocks. Seal numbers incrementally increased between surveys from 457 (Sep.) to 565 (Oct.) then decreased to the lowest count for the final survey 399 seals (end Nov.) The proportion of adult sexes (male vs. female) varied across the surveys with more males than females being present in the September and mid-November surveys and more females than males being present in the October and the end of November surveys (**Table 2**). The variability in total counts, sex ratio and age classes observed across the surveys highlights the importance of gathering detailed long-term data on this population; data from single surveys should be interpreted with caution due to the considerable levels of spatial and temporal variation in these population parameters within and across seasons and years.

Most seals observed were adults (81%; 399 ± 54 mean ± 1 s.d., min = 327, max = 446; n = 4 surveys). More adult females (208 ± 59; **Figure 4**) were observed than adult males (192 ± 47) and juveniles (48 ± 25). Only a small number of seals were not sighted clearly enough to determine their age/sex (unknown age/sex: 35 ± 23 seals per survey). Between two and four different live entangled seals were recorded each survey. Despite taking considerable care to avoid disturbing seals, some of those observed hauled out moved into the sea (8%; 39± 30) whilst the survey boat was in their vicinity.

Figure 4. Typical examples of adult male, adult female and juvenile grey seals.

Table 2. Counts of seals by surveys, sex and age class.

Survey	Month	Seals observed	Hauled out	In sea	Adult male	Adult female	Juvenile	Weaners and moulted pups	White coat pups	Unknown sex/age	Entangled	Disturbed
1	Sep.	457	398	59	227	163	52	0	5	10	3	62
2	Oct.	565	496	69	153	293	45	1	14	59	3	66
3	Nov. mid	549	507	42	237	196	78	6	11	21	4	4
4	Nov. end	399	388	11	149	178	17	0	5	50	2	25

Sites of Special Scientific Interest (SSSI)

Most seals were observed at two SSSIs – the Western Rocks (108 ± 49; mean ± 1 s.d.; n = 4 surveys) and the Eastern Isles (282 ± 48). Seals were observed at two other SSSIs – Island 11 (80 ± 31) and the Norrards (13 ± 10). A small number of seals were also observed at Island 31 (2 ± 2) which is part of the Samson SSSI and in St Martins SSSI (9 ± 9).

SSSIs supported differing proportions of males, females and juveniles – Island 11 and the Eastern Isles SSSIs had proportionally more adult males (52%, 44% respectively) whilst the Norrards SSSI and Western Rocks SSSI had proportionally more adult females (61%, 62% respectively).

Spatial patterns in grey seal haul out use

The distribution of seals hauled out across the archipelago varied both spatially and temporally (**Figure 5; Table 2**). More adult males than females were observed on Island 11 and the Eastern Isles with more adult females than males being counted on the Norrards and Western Rocks. This pattern was likely influenced by two adult male dominated beaches – one on the southeast side of Island 11 and a second on the east side of Island 62 in the Eastern Isles. All the other islands (with the exception of Island 14) had more adult females than males.

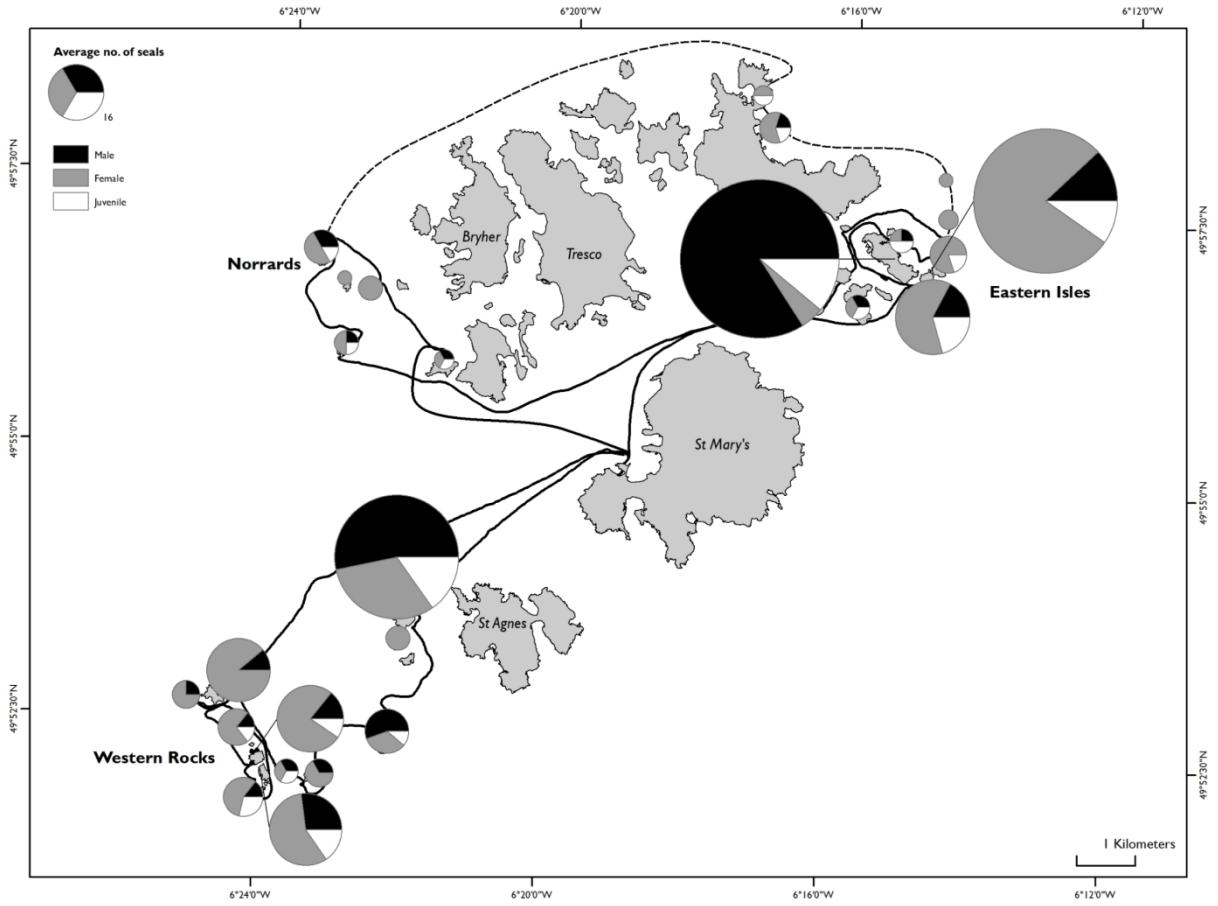

Figure 5. Mean numbers of seals observed (symbol size), with mean proportion by age and sex class (black, grey and white segments respectively) from boat-based surveys. Survey track (solid line). Modified track due to weather conditions (dashed line).

Land-based surveys (seal pups)

Landing surveys to count grey seal pups were conducted during all four surveys with 198 unique pups identified (192 alive: 6 dead). The total number of unique pups was calculated by subtracting the total number of fully moulted pups after the first survey from the total number of pups observed. This number represents the minimum estimate of seal pups produced across the four islands surveyed. Moulted pups can remain at their natal site for differing periods of time and up to 29 days (Fedak and Anderson 1982). Given the duration between surveys was less than this period it was necessary to take the precautionary approach of only counting white coat pups (with the exception of the first survey, when all weaned pups represented newly encountered seals).

Most seal pups were encountered during the October survey (**Figure 6**), and most seal pups were counted on the island of Island 11 (n=149, **Figure 6**), followed by Island 5 (n=15), Island 31 (n=15) and Island 24 (n=9). From boat-based surveys, grey seal pups were also observed on four other islands; Island 14 (n=1), Island 67 (n=1), Island 25 (n=1) and Island 36 (n=1).

Six dead pups were observed over the four surveys representing a mortality rate of 3% (6 of 198 pups).

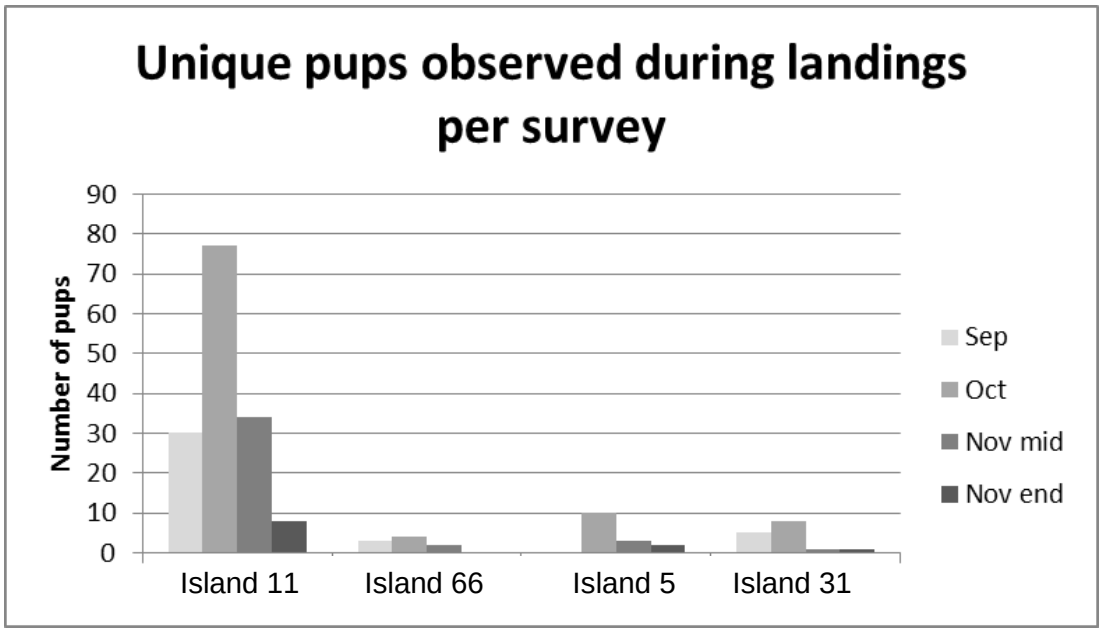

Figure 6. Spatio-temporal pattern of grey seal pups observed from land-based surveys.

Pupping ages and locations

Pups at all weeks of development were observed from new born pups (week 1) to rotund (week 2), and fully moulted, weaned pups (week 3).

Table 3. Frequency of observed live (and dead) simplified pup development stages.

Stage	Sep.	Oct.	Nov. mid	Nov. end	Total
Week 1	13 (0)	24 (1)	9 (1)	0 (0)	46 (2)
Week 2	11 (0)	21 (2)	7 (0)	2 (1)	41 (3)
Week 3	14 (0)	56 (1)	25 (0)	10 (0)	105 (1)
Total	**38 (0)**	**101 (4)**	**41 (1)**	**12 (1)**	**192 (6)**

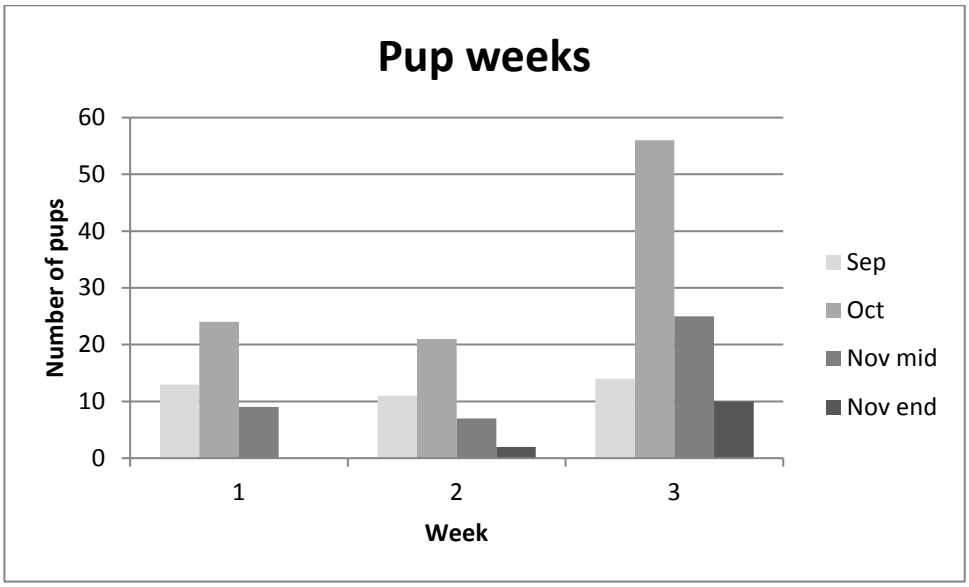

Figure 7. Frequency of simplified pup age development scores.

The location of each pup was recorded using a hand-held GPS receiver (**Figure 8**). Most pups appeared to occupy unique sites that had not been used by previous pups in the 2016 season. On Island 31, most seal pups were found on the north and eastward facing sides, corresponding with the most shelter from prevailing weather. On Island 11, most pups were located peripherally in the northern half of the island with a smaller number found down the east side of the southern half of the island. Pups encountered on Island 24 and Island 5 were found on the highest land available towards the centre of the islands.

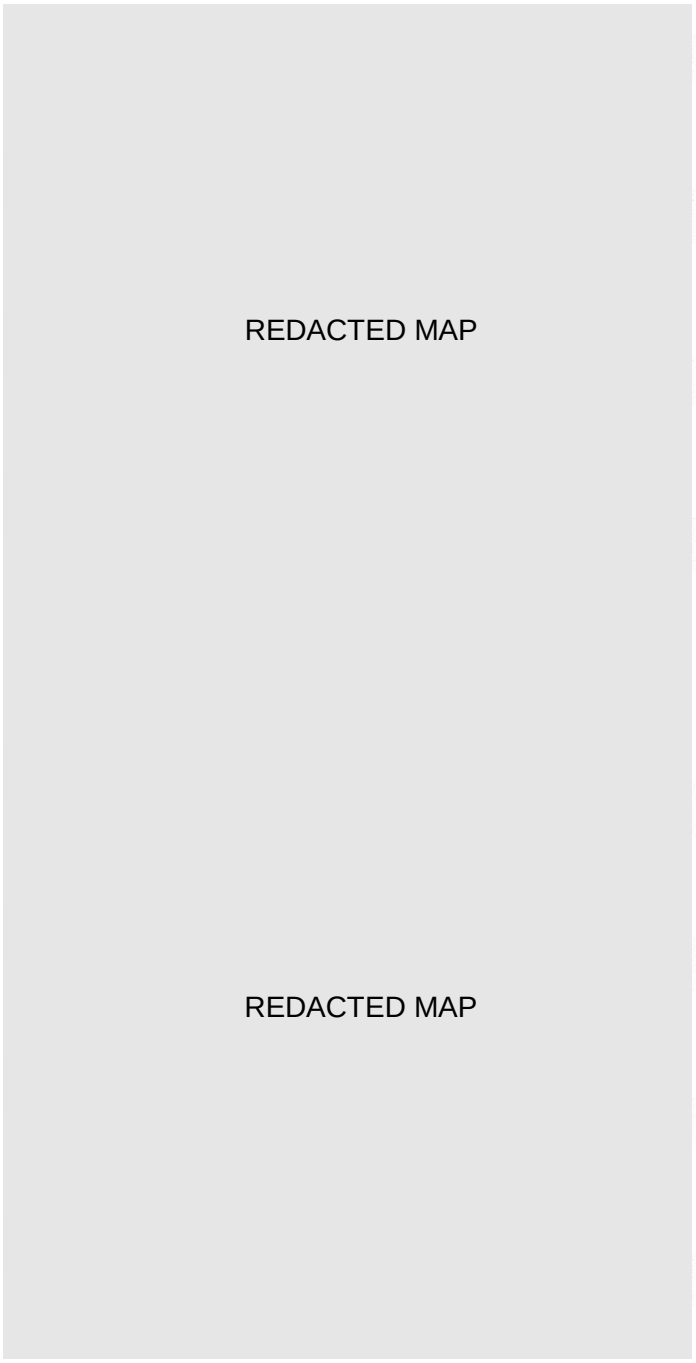

Figure 8. Pup locations recorded during landings. Blue contours indicate highest astronomical tide and mean low water springs.

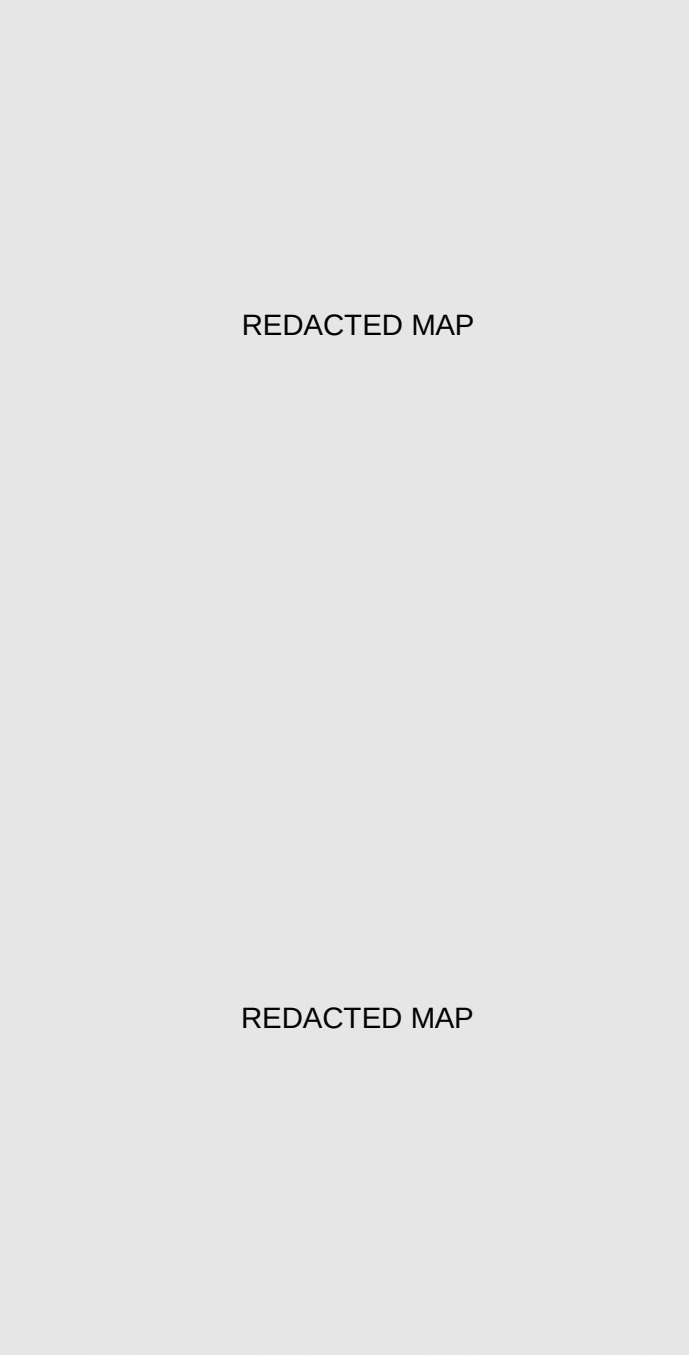

Figure 8. (Continued) Pup locations recorded during landings. Blue contours indicate highest astronomical tide and mean low water springs.

Pup production estimate

The pup estimation model suggested that pupping began around 1st Sep. and ended around 9th Dec. Total estimated production for the four islands was 234 grey seal pups (median), range 215 to 256 pups (25th and 75th percentiles respectively). This method of estimation assumed that the peak of the pupping season was surveyed (October survey) and that the distribution of pup births followed a normal distribution. It was assumed that pups fully moulted and dispersed between 17 and 23 days.

Unmanned Autonomous Vehicle with Thermal-IR

Weather conditions encountered during the late November survey were at the limits of safe operational practice from drone-based surveys. Conditions on the first day of surveying prevented data collection. Wind speed dropped on the second day of survey and two island surveys were completed. No seal pups were detected on either Island 24 or Island 31 by either the drone optical camera, the drone thermal-IR camera or by visual census by surveyors. A single young pup (stage 5) was present in the fringing waters of Island 31, however, it was sufficiently wetted to be opaque to the thermal-IR camera and could not be detected in video, potentially due to its cryptic pelage.

Photo identification of individual seals

Despite the limited time available during the four boat and land-based surveys, nine adult seals (F0, F61, N1, N55, LIZ5, LIZ97, LIZ203, DP315 and S415) were identified from the southwest England photo identification catalogues (six females and three males). Six of these nine seals have been identified at four other sites; including, Longships (Lands End; n=1), North coast of Cornwall (n=2), and the Lizard Peninsula (South coast of Cornwall; n=2).

While CSGRT's photo-identification effort around the Isles of Scilly has been limited by access to funding, a total of 48 different seals photographed in the Isles of Scilly (22 females, 26 males) have been re-identified from at least one other site outside the Isles of Scilly. These seals have been identified as far afield as Skomer in Pembrokeshire Marine SAC (n=2; Wales), St Austell Bay (n=1; southeast Cornwall), North Cornwall (n=5) and North Devon (n=1). Between them, these seals link the Isles of Scilly to at least 16 other sites across southwest Wales and England.

Comparison of 2010 and 2016 surveys

Seal counts overall appeared to be stable between 2010 and 2016 (507 vs. 493; Table 4), yet there was some difference in the age and sex class of seals observed as well as their temporal and spatial distributions.

In 2016, there were more adult females observed (**Table 4**), and there was a reduction in the number of juveniles observed on the Eastern Isles, Norrards and Western Rocks. Fewer seals were observed in 2016 on the Western Rocks of all age and sex classes. More seals were observed on the Eastern Isles despite a decrease in the number of juveniles observed here. Whilst the top nine islands occupied by seals remained the same, changes to their relative rankings (based on total counts of seals; when benchmarked against 2010 data) were evident in some cases (**Table 5**).

Pupping appeared to be stable on Island 24, Island 5 and Island 31 (**Table 6**), although this observation is based on relatively few pups as compared to Island 11. The estimate of pup production for 2016 was greater than in 2010.

Table 4. Seal counts from boat-based surveys, with breakdown for SSSI.

Survey total(s)	2010	2016
All seals	507 +/- 177	493 +/-78
Adult male	195 +/- 80	192 +/- 47
Adult female	160 +/- 54	208 +/- 59
Juvenile	131 +/- 48	48 +/- 25
Western Rocks SSSI		
All seals	238 +/- 97	108 +/- 49
Adult male	82 +/- 37	22 +/- 10
Adult female	101 +/- 48	67 +/- 33
Juvenile	50 +/- 25	9 +/- 7
Eastern Isles SSSI		
All seals	246 +/- 184	282 +/- 48
Adult male	68 +/- 31	125 +/- 43
Adult female	35 +/- 11	102 +/- 32
Juvenile	74 +/- 39	32 +/- 15
Norrards SSSI		
All seals	27 +/- 12	13 +/- 10
Adult male	9 +/- 4	2 +/- 2
Adult female	12 +/- 5	8 +/- 4
Juvenile	4 +/- 5	2 +/- 2
Island 11		
All seals	51 +/- 49	80 +/- 31
Adult male	34 +/- 41	42 +/- 27
Adult female	10 +/- 9	25 +/- 14
Juvenile	2 +/- 2	4 +/- 4

Table 5. Mean count of grey seals and relative ranking of island by count.

Islands	**Rank & Count +/- 1 s.d. (2010)**	**Rank & Count +/- 1 s.d. (2016)**
Island 67	1 85 +/- 23	4 29 +/- 11
Island 66	2 58 +/- 45	2 108 +/- 42
Island 5	3 51 +/- 57	5 27 +/-12
Island 11	4 51 +/- 49	3 80 +/- 31
Island 6	5 44 +/- 7	5 27 +/- 12
Island 14	6 37 +/- 31	8 10 +/- 7
Island 62	7 29 +/- 35	1 131 +/- 63
Island 2	8 27 +/- 11	7 21 +/- 18
Island 7	9 19 +/- 10	9 8 +/- 10

Table 6. Grey seal pup counts by island and production estimate.

Unique live pups	**2010**	**2016**
Island 11	45	149
Island 66	9	9
Island 5	14	15
Island 31	11	15
Other	3	4
Pup production (n)	89 to 134	221 to 234
Duration of pupping season	144 days	100 days

Discussion

Survey frequency

The limitations surrounding survey logistics, including tide, sea conditions, wind, flight availability, accommodation, boat and survey team availability make surveying for grey seals and their pups at regular intervals particularly challenging. Furthermore, suitable conditions for surveys become progressively shorter during the winter period and logistically there are only two potential survey opportunities of three consecutive days at the end of November and into December when seeking to survey within relevant tidal conditions and day light hours.

Boat-based seal counts

The peak number of seals observed during surveys occurred in October 2016, from which point they declined in to late November. Seal numbers on the Isles of Scilly can vary between months, typically reaching a peak in the winter (Sayer et al 2011). Whilst seal counts overall were comparatively similar between 2010 to 2016, the intra-annual pattern was somewhat different, with peak counts in October (in 2016) as compared to peak counts in December (in 2010). The temporal change in peak counts between the years may reflect prevailing weather conditions.

The adult grey seal sex ratio was near equal (49% male; 51% female; mean average across surveys) in 2016, this is in contrast to 2010, where the ratio was male dominated. The spatial pattern of male, female and juvenile grey seals encountered during surveys in 2016 was heterogeneous across the archipelago. More adult females were counted in October and at the end of November whilst more adult males were recorded in September and mid-November. The number of juveniles observed declined between surveys in November and was lower in all 2016 surveys as compared to 2010 surveys.

Island preference by seals largely persisted between 2010 and 2016 with the same top nine ranked islands on both surveys. Only three of these islands had more adult males than females (Island 62, Island 11 and Island 14) and two of these islands (Island 62 and Island 11) have male dominated beaches presumably used by non-breeders.

Land-based pup counts

The most developed pup observed during the first survey (September) indicated pupping occurred during the first week of September and the least developed pups recorded on the fourth survey suggested pupping continued into the last week of November. The extent of the pupping season is likely to have been longer than that revealed during the 2016 surveys. We estimated the pupping season to be between 01/09/16 and 09/12/16 – a duration of 100 days. Given financial and logistical resources, surveys in August and December were not possible, although these may have confirmed the true extent of the season. The pup production estimate for 2016 was 221 to 234.

The peak month for pupping was October followed by mid-November and September. This pattern is similar to that observed on the north coast of Cornwall for pups born on exposed beaches between 2000 to 2010 (Sayer, 2010). In Cornwall, however, a small number of pups have been observed throughout the year.

Island 11 SSSI supported the greatest number of pups (n=149), followed by Island 5 within the Western Rocks SSSI, Island 31 in the Samson SSSI and Island 24 on the Norrards. Between 2010 and 2016, pupping on Island 24, Island 5 and Island 31 was comparatively similar, whilst pup numbers on Island 11 trebled (in 2016). The reasons for this increased pupping effort are unclear, but might indicate improved feeding opportunities for females, appropriate weather conditions, a re-distribution of adult female seals to Island 11 due to disturbance from elsewhere or sub-optimal conditions at previous pupping sites. Individual variability must also be considered. Seal pups in 2016 were predominately located on eastern and northern sides of Island 11 and Island 31; this likely corresponds with these islands' most sheltered sides, both having greater fetches (distances of exposed sea) on their southwest sides, the direction of the prevailing winds and seas. Island 24 and Island 5 are somewhat higher but sheltered by other islands and are much smaller in area.

Mortality rates of pups can be 15% in the weaning period and an additional 40 to 60% at 12 to 18 months (Davies et al 2001). Surveys in 2016 suggested a 3% mortality rate of pups in the weaning stage compared to 7% in 2010. These are minimum estimates as seals encountered were not followed to post-weaning dispersal.

Unmanned aerial vehicle deployment

The logistics of flight preparation, planning and execution proved important pilot work for drone based surveying. Limited funding and logistical constraints meant only a single two-day survey could be completed, and nearing the end of the season when detection of seals might reasonably be expected to be low. The developed protocols will undergo further refinement with regards data capture techniques (gathering still images at high frequency; as compared to continuous video) and flight planning. The technique shows promise for undertaking future surveys that are likely minimally invasive and where risks to surveyor health and safety suggest remote technique might offer a lower-risk approach. A drone-based approach may also enable a larger number of islands to be surveyed directly. Drone surveys will always require boat access and so the potential for cost savings may be limited, however, drone surveys provide data that can be repeatedly checked after the event and offer some improvements in health and safety for survey staff. The most optimal situation might be the interface of foot patrols on a selection of islands that have yet to be surveyed in detail and drone-based surveys for islands where existing knowledge on topography and rock formation exists (hence pre-existing knowledge on levels of detectability from an aerial point of view).

Comparison of 2010 and 2016 surveys

Differences the in counts between surveys along with an increase in pup production warrants further investigation into other population parameters such as mortality and migration, particularly as entanglement of seals in materials of anthropogenic origin and bycatch in fisheries can lead to high relative levels of seal rescue and mortality in this region (Allen *et al*., 2012; Crosby, 2015; Jarvis, 2015; Northridge *et al*., 2010; Northridge *et al*., 2013)

Photo identification

Nine different seals were identified from existing photo-ID catalogues during the four surveys. Opportunities for photo ID were limited due to the challenging schedule of conducting a population census during each survey and the need to undertake land-based counts of pups. Even with limited

photo ID work it was possible to confirm Isles of Scilly SAC habitat is functionally linked by grey seals to sites across southwest Wales and England (at least to Pembrokeshire Marine (EMS), to north Devon and St Austell Bay in the east).

SAC attribute assessments

The following observations are made regarding the relevant SAC monitoring attributes for grey seals:

1. Pup production: Increase in unique live pups from 79 in 2010 to 192 in 2016. Pup production estimate from 89-134 (min. to max.) in 2010 to 221-234 in 2016. Mean population count was stable across four surveys in autumn and winter: 2010 (n=507) and 2016 (n=493).

2. Number of putative breeding females: Increase from 160 ± 54 in 2010 to 208 ± 59 in 2016. This is a count of assumed adult females, not all adult females may be breeders.

3. Mortality in the breeding colonies: uncertain. Insufficient information available.

4. The distribution of grey seal pups: Seal pups were identified on six islands in 2010 and on eight islands in 2016. In both 2010 and 2016, the majority of pups were observed on Island 11 SSSI, where seals are not a listed species in the SSSI/SAC citation.

5. Accessibility of sites for breeding: No access issues were observed in 2010 or 2016.

Four additional features were monitored for grey seals on the Isles of Scilly:

6. Disturbance (based on displacement of seals during surveys): 10% in 2010 and 8% in 2016.

7. Extent of breeding, moulting and haul out sites measured in terms of total area:

Breeding sites: In 2005, pups were observed at Island 11, Island 9, Island 2, Island 24, Island 25 and Island 5. In 2010, from the boat-based surveys and landings, pups were observed on Island 11, Island 24, Island 25 and Island 5, as well as Island 14 and Island 31. In 2016, from the boat-based surveys and landings, pups were observed on Island 11, Island 24, Island 25 and Island 5, Island 67 and Island 36, as well as Island 14 and Island 31. There is evidence that seals previously pupped on the Eastern Isles (Sayer et al 2011). No pups were observed there in 2005 or 2010, but one was present on Island 67 in 2016.

Moulting sites: No monthly surveys were completed of the moulting sites in either 2005, 2010 or 2016. This is a priority for future research.

Haul out sites: In 2010, seals were observed hauled out at 30 island sites – 10 in the Eastern Isles SSSI, nine in the Western Rocks SSSI, five in the Norrards SSSI, two in the Samson SSSI, one in each of the following SSSIs – Annet, St Agnes, St Martin's, St Mary's. In 2016, seals were observed hauled out at 30 island sites – 10 in the Eastern Isles SSSI, nine in the Western Rocks SSSI, four in the Norrards SSSI, three in the St Martins SSSI, and one in each of the following SSSIs – Annet, Samson, St Agnes, St Mary's. These observations are influenced by the chosen survey route; which was constant between 2010 and 2016.

8. Extent of the breeding season: The pupping season was estimated to be 144 days in 2010 and 100 days in 2016 (using the same estimation technique).

9. Entanglement observed on live seals: 1% of seals (mean across four surveys) were observed with evidence of entanglement in 2010 (n=22) and 2016 (n=12).

Recommendations

The lack of an increased seal count alongside an increase in pup production warrants further investigation. Additional monthly seal counts across the calendar year would provide greater detail on grey seal inter and intra annual variation and would enable investigation into spatial / temporal change in habitat use by grey seals across the Isles of Scilly SAC. Further, a survey of moulting season sites is needed to fully assess the extent of sites used by seals, this is currently a significant data gap in robustly assessing the status of site attributes.

Pup counts on a more frequent basis than the minimum of once every six years would enable data to be sufficiently robust for power analysis to detect trends in pup production (Sayer et al, 2011).

Landings are essential on Island 11, Island 24, Island 5 and Island 31. Additional landings should be considered on Island 9, Island 2, Island 6 (Westcott, 2008), Island 25 (Westcott, 2008), Island 14 and Island 67 (from 2016 boat based observations of white coated pups.)

Unmanned aerial vehicle technology warrants further deployment following this successful initial trial and may minimise the need for future landings-based surveys, however, some degree of foot patrols will always be necessary to ensure estimates of drone detectability of seals remain valid.

Intensive and focused effort-based photo identification work during each of the three seal seasons (pupping, moulting and summer) over a period of several days would support an assessment of habitat use at the individual level and may reveal how sites are functionally linked within and beyond the SAC.

A quantitative investigation into the levels of disturbance experienced by seals during the peak tourist season.

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Appendix 1. Site references

Island No.	Island name (REDACTED)	SSSIs relevant to seals
1		Western Rocks
2		Western Rocks
3		Western Rocks
4		Western Rocks
5		Western Rocks
6		Western Rocks
7		Western Rocks
8		Western Rocks
9		Western Rocks
10		Western Rocks
11		Island 11
12		Western Rocks
13		Western Rocks
14		Western Rocks
15		
16		
17		
18		
19		Norrards
20		Norrards
21		Norrards
22		Norrards
23		Norrards
24		Norrards
25		Norrards
26		Norrards
27		Norrards
28		Norrards
29		Norrards
30		
31		Samson
32		Samson
33		Samson
34		Samson
35		Samson
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50		
51		
52		
53		
54		
55		
56		
57		Eastern Isles
58		Eastern Isles
59		Eastern Isles
60		Eastern Isles
61		Eastern Isles
62		Eastern Isles
63		Eastern Isles
64		Eastern Isles
65		Eastern Isles
66		Eastern Isles
67		Eastern Isles

Appendix 2

Available from Natural England

www.naturalengland.org.uk

All photos taken during the surveys