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Scroby Sands Offshore Wind Farm: Seal Monitoring:

Analysis of the 2006 post-construction aerial surveys and summary of the monitoring programme results from 2002-2006

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EXECUTIVE SUMMARY

Background information & methods

Over the period October 2003 to August 2004 E.ON UK Renewables Offshore Wind Limited constructed a 60 MW wind farm comprised of 30 x 2 MW turbines on Scroby Sands, a dynamic sand bar system approximately 2 km offshore from North Denes, Great Yarmouth, Norfolk. The development is located about 2 km north of an area used by Harbour seals *Phoca vitulina* as a breeding and haul-out site for at least a century, and more recently (from 1958) by Grey seals *Haliochoerus grypus* for hauling out. The former small breeding colony of the latter on Scroby Sands was abandoned following the covering of the bank at high tide from 1966 onwards. Breeding now takes place on a mainland beach some 20 km away to the north near Horsey Gap.

The Schedule to Licence required that a monitoring programme be carried out to determine the impact of the wind farm on the seal populations. This was specified as two aerial photographic surveys from fixed wing aircraft per month at low water for the six summer months (April to September) pre, during and post construction. Baseline pre-construction data was gathered in 2002 and 2003, construction data was gathered in 2004, and post-construction data was gathered in 2005 with the addition of 2006 following significant change in local seal populations. Further recommended modifications to the survey programme included further surveys to assess Harbour seal pup production during summer and winter surveys to assess the use of the Sands by Grey seals in particular in this period.

In total, 64 surveys were carried out during the study period from March 2002 to October 2006, exceeding the FEPA licence requirements. However, it should be highlighted that monitoring was only a specified requirement from April-September, which meant that no surveys were undertaken during the period of pile driving from October 21st 2003 to January 1st 2004, known to be the most disturbing element of the construction process for seals from studies conducted at other offshore wind farms (OWF's) in Sweden and Denmark. In summary, it has been calculated that the noise of pile-driving may be detected by seals at beyond 80 km from the source, with the potential for some form of response through disturbance of up to 20 km and the prospect of hearing damage at up to 400 m. Severe injuries (most likely resulting in death) cannot be ruled out in the immediate vicinity of pile-driving.

Results & Discussion

Statistically significant changes in the numbers of both seal species and thus species composition were observed during the monitoring programme of Scroby Sands. The decline in numbers of Harbour seals hauled out and consequently breeding colony productivity coincided with the construction of the wind farm (Figure A). Although Harbour seals were affected by a further outbreak of Phocine Distemper Virus (PDV) in 2002, which formerly decimated populations in 1988, and are known to be decline nationally for reasons as yet undetermined, the timing of the outbreak and the nature of the general decline cannot explain the step-down response at Scroby Sands.

Although some recovery was noted, numbers remained depressed during the operational phase during 2005 and 2006. No monitoring was undertaken during the period of pile driving and therefore the actual response of seals was not determined, although evidence from the literature reinforced by anecdotal information from local sources suggests that Harbour seals would almost certainly have temporarily abandoned Scroby Sands (between a minimum of 1.5 and maximum of 7 km between turbines and haul-out areas) in this period. One postulated mechanism to account for the apparent lack of return of individual seals concerned displacement to other sites (e.g. Wash, Blakeney Point, Orford Ness), which all far exceed the typical foraging distance of Harbour seals (45 km). This would suggest a reduced prospect of routine return to Scroby Sands. Moreover, a notable increase in Grey seals also led to consideration of the prospect of interaction between the two species (see below).

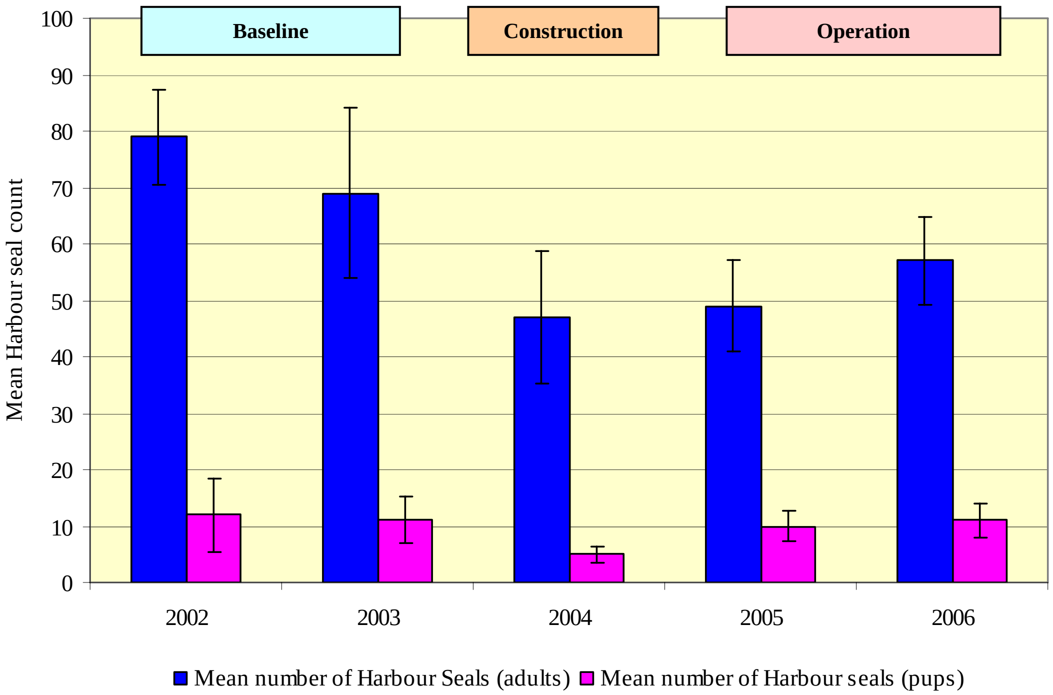

Figure A. Mean (± 1SE) number of Harbour seals and pups during aerial surveys of Scroby Sands during the baseline (pre-construction) construction and operational phases of the Scroby Sands OWF from 2002-2006.

Despite press reports to the contrary, there was no evidence of a serious operational affect on Harbour seals including abortion, malformation and abandonment. The reported higher incidence of 'rescued' seals most likely resulting from a series of documented severe summer storms, which had a dramatic effect on other coastal wildlife (e.g. mortality of >1,000 Sandwich tern *Sterna sandvicensis* chicks in their internationally important North Norfolk colonies). There is historical precedent of a catastrophic effect of storm events on survival of newly born Harbour seals, both directly and indirectly through separation from their mothers at Scroby Sands. Notwithstanding the lack of evidence for a significant impact of operation, an additional lower level of impact, most likely through a negative reaction to boat traffic, over and above the impact of displacement during construction, could not be discounted.

Industry standard matrix analysis, suggested the combination of *medium* sensitivity with a *high* magnitude of impact (>20% of population affected) results in a *moderate* significance of construction impact on haul-out counts for Harbour seal and a similar *moderate* significance for breeding success, based on pup counts. Such impacts are undesirable and give rise to concern, but may be tolerable depending on their scale and duration.

The statistically significant increase in Grey seals during the construction phase of the OWF, which was maintained subsequently (Figure B), was thought to be caused by coincidental immigration into the area over the winter of 2003/04 with an additional, but undefined contribution from continued successful local recruitment. Such immigration events have occurred previously leading to the colonisation of both Norfolk and Lincolnshire. However, judging from population trends at different colonies, the recent event was most likely caused by a rapid expansion of the Donna Nook colony in Lincolnshire from which Grey seals are pre-adapted to sandy beaches.

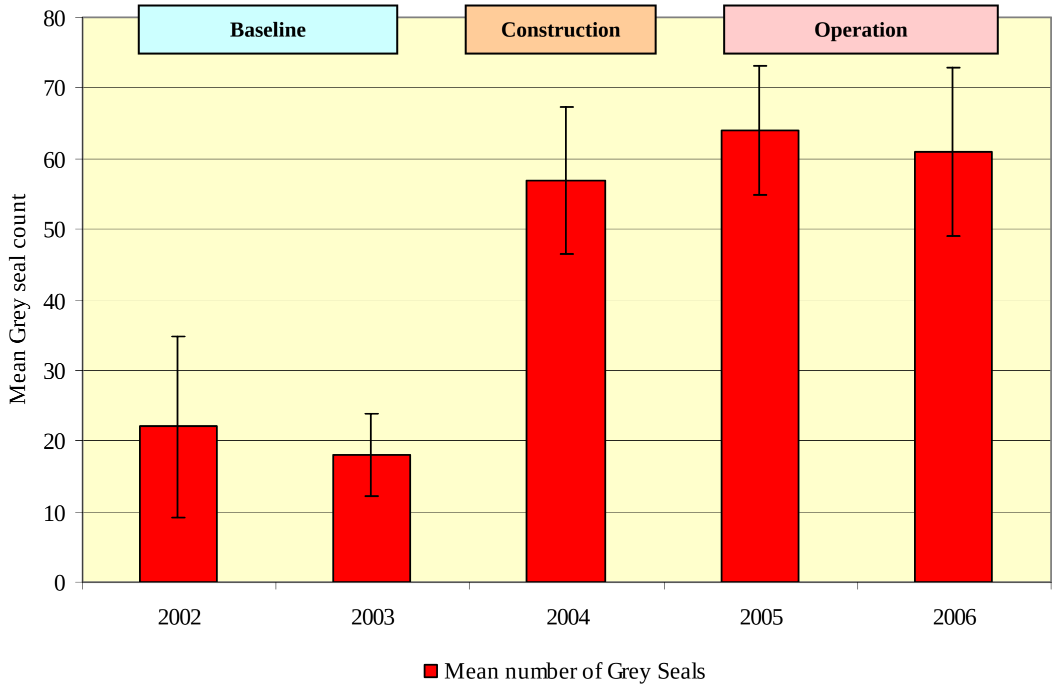

Figure B. Mean (± 1SE) number of Grey seals during aerial surveys of Scroby Sands during the baseline (pre-construction) construction and operational phases of the Scroby Sands OWF from 2002-2006.

There was thus no obvious effect of construction of the wind farm upon Grey seals, with pile-driving undertaken in the breeding period of Grey seals when only a few (<15 ind.) seals (mostly geriatric bulls) remain on Scroby. There was no evidence of any negative effect on local breeding success at Horsey ~20 km from Scroby Sands. However, an indirect, albeit positive impact of the wind farm through competitive release as a result of the decline in Harbour seals was thought to be plausible.

Conclusions & Recommendations

The monitoring programme at Scroby Sands has added considerably to the knowledge base of the impact of wind farm construction and indeed any development near seal haul-out and breeding sites. This is particularly pertinent to the development of Round 2 sites in the Greater Wash, which contain by far the largest population of Harbour seals in England and are increasingly being used by Grey seals.

Whilst a construction impact should intuitively be of short duration, restricted to the period of works activity, this has not proved to be the case for Harbour seal at Scroby Sands as both haul-out counts and breeding success have continued to be depressed into the longer term and the *moderate* significance impact has been maintained into the operational period. This is of concern and it is recommended that monitoring be continued in the longer term, as this will would prove invaluable in determining the longer-term impact of the operational wind farm at Scroby and of offshore wind farms in general, and help tease out the relative impact of the large-scale development of the Outer Harbour within the range occupied by Scroby Sands wind farm as well as and longer term trends in seal populations.

Monitoring to the same intensity as conducted in the impact assessment, but on a three-year rolling programme is thought to be of value, although the same effort may be partitioned in a different way to best suit the aims of monitoring. Whatever the case, additional data (i.e. wind speed, direction, tidal state etc) that may influence haul-out counts should also be gathered as a matter of course.

Finally, given the continued development of OWF's leading to the recent announcement of Round 3, consideration was given to a number of issues surrounding the site selection, construction, operation and monitoring of offshore wind farm in the form of a series of recommendations of best practice. In brief it was recommended that:

- For sites <20 km to haul out sites it is recommended that alternative methods of construction other than the use of monopiles are considered.
- Where pile-driving is undertaken 1) pile driving should not be undertaken when seals are pupping, 2) when sites are close together it is recommended that pile driving does not occur on more than one site at a time, 3) seal scrammers should be used to deter seals from the area before pile driving starts to displace seals and avoid inflicting hearing damage, 4) haul out sites <20km away should be monitored before, during and after pile driving at wind farms from seal haul out sites.
- To minimise disturbance from vessels in construction and operation, vessel routes to and from sites should not pass close to seal haul-outs unless an alternative is not available. Observational monitoring of responses of seals to boats should be used to ensure that boat routes used are not disturbing seals.
- Wind farms are not built within 1 km of haul out sites, as operational noise is likely to be detectable by seals at this distance
- Further work is required to resolve whether seals continue to use wind farm areas once the development is installed or whether this decreases habitat favourability and if some degree of habitat loss/displacement could occur.
- Caution is advised if building numerous sites, or sites of significant size near Harbour seal colonies as there is potential for significant cumulative impacts.
- Monitoring should be designed to also address the causes of any changes detected (through additional methods if required) in order to actively investigate the mechanisms by which seals might be affected by the development.
- Where aerial surveys of haul-out counts are conducted, data quality can be improved by investigating whether other environmental variables significantly affect haul out counts and correcting to account for these influences where necessary.

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1. INTRODUCTION

In August 2004, E.ON UK Renewables Offshore Wind Limited (formerly PowerGen Renewables Development Ltd.) completed construction of a wind farm comprised of 30 x 2MW Vestas V80 turbines on Scroby Sands, a dynamic sand bar system approximately 3 km offshore of Great Yarmouth, Norfolk.

The Schedule to Licence stated that a monitoring programme, as agreed with the Sea Mammals Research Unit (SMRU) should be carried out to determine the impact of the wind farm upon populations of Harbour[1] seals *Phoca vitulina* and Grey seals *Haliochoerus grypus* using the area. This was specified in the licence as two fly-overs per month at low water for the six summer months April to September inclusive, before during and after construction, the latter of which was carried out in 2005.

Following initial analysis, ECON (2005a) recommended that further monitoring, surplus to the licence requirements be carried out in 2006. This was to confirm whether Harbour seal counts were indeed improving, as was suggested by the 2005 data following an apparent decline during the construction period in 2004 (ECON 2005b).

This report details the analysis of this additional monitoring as well as summarising the overall findings of the study. The results of additional winter surveys carried out in November and December 2005, also surplus to the licence requirements[2], are also presented and discussed.

2. BACKGROUND INFORMATION

The content of previous seal reports is summarized in Table 1. In brief, the two baseline reports (ECON 2004ab) provided a historical review of the Scroby Sands seal colony (summarised in Appendix III) and provided recommendations for additional surveys, as well as an analysis of abundance and distribution of the two seal species in the respective years. Information from other offshore wind farm sites (OWF's) near seals such as Horns Rev and Nysted in Denmark was reviewed, although this work, based around the use of satellite telemetry as a means of tackling largely site specific questions, was of only minor relevance to the seal monitoring programme at Scroby.

Analysis of the Harbour seal data from 2005 revealed no significant differences in mean counts between the baseline data (2002 and 2003), or the construction data (2004). Nonetheless, comparison of mean (±1SE) counts gave rise to some concern that numbers had reduced in 2004 (52 ± 8.74) and 2005 (57 ± 10.05) from baseline values in 2002 (107 ± 14.64) and 2003 (82 ± 10.70). However although an increased median value in 2005 (67 compared to 48 in 2004) indicated that although Harbour seals may have been displaced during construction, there was some evidence of their return to the area by the following summer.

[1] Formerly known as Common seal
[2] These were in fact carried out in error and not on recommendation by ECON

Table 1. Summary of previous reports (ECON 2004ab, 2005ab)

Years	Stage	Report content	Main findings
2002 & 2003 (ECON 2004ab)	Year 1 & 2 Baseline data	Historical review of the colony	Used as Harbour seal haul out for at least a century, Grey seals first identified late 1950s. Both species used to breed on Scroby when it was exposed, although Grey seals now breed on the mainland beaches.
		Analysis of 2002 data	Harbour seals observed to breed on Scroby, and are the dominant species.
		Analysis of 2003 data	No significant differences in total number of seals between 2002 and 2003. Slight change in haul out site areas between years
		Recommendations	Three additional surveys to be carried out during the pupping period to obtain a more reliable measure of Harbour seal pup productivity. (This was carried out in 2004 & 2005). GPS points to be taken on each survey so that more precise locations of haul out sites are known. Winter monitoring to be carried out in at least one year to verify the predicted seasonal usage of Scroby by Grey seals. (This was carried out in winter 2004/2005).
2004 (ECON 2005b)	Year 3 Construction data	Analysis of 2004 data	Significantly fewer Harbour seals hauled out in 2004 than in 2002. Harbour seal recruitment poor, although severe weather was believed to be at least partially responsible. A weak negative correlation was found between the number of boats on the wind farm site and the number of Harbour seals hauled out. There were significantly more Grey seals in 2004 than in 2003, indicating a major difference between the potential responses of the two species to wind farm construction.
		Review of data from other wind farms constructed near seal haul out sites	Nysted, Denmark: satellite telemetry carried out on four Harbour and six Grey seals. Harbour seals were identified as potentially the most vulnerable since Grey seals were less site faithful and had greater home ranges. Horns Rev, Denmark: satellite telemetry on 10 Harbour seals revealed substantial variation in foraging patterns, although seemed to identify some consistently used foraging routes. The wind farm acted as a corridor for movements between other foraging areas, and the paucity of fixes from within it meant that it was impossible to evaluate whether construction had any sort of impact.
		Discussion of potential impacts & mechanisms	Potential negative effects of the wind farm site included: Noise during construction (in particular) and operation. Disturbance from physical presence of turbines (e.g. moving blades) during construction & operation. Disturbance from associated human activity.
		Recommendations	Monitoring to continue in order to assess any further changes in Harbour seal numbers.
2005 (ECON 2005a)	Year 4 Post-construction data	Analysis of 2005 data in context of the complete monitoring programme with regard to abundance, breeding success and distribution	Significantly more Grey seals were present in 2004 than in 2003 and in 2005 than in 2002 and 2003, indicating a strong increase between the baseline (2002 and 2003) and construction/post-construction years. The 2005 Harbour seal pup counts, which were poor during the construction year, improved in 2005, but were still low in comparison to the baseline years. Haul-out areas in the south-east and west of Scroby were used consistently throughout the four years, although there was also a substantial amount of inter-annual variation.
		Recommendations	Further monitoring in 2006 to confirm the status of the Harbour seal population.

Consequently, further monitoring was recommended to determine whether Harbour seal numbers had continued to increase, and to address concerns relating to a potential decline in haul-out and pup counts during the construction year.

3. AIMS

In summary, the specific aims of this report were to:

- Analyse the data from the two aerial surveys carried out over winter in 2005.
- Analyse the date from the eleven surveys carried out over summer 2006.
- Compare this data against the baseline data gathered in 2002 and 2003, the construction data gathered in 2004, and the post-construction data gathered in 2005.
- To evaluate the current status of the Harbour seals at Scroby, with particular reference to the potential impacts of construction-related disturbance in 2004.

4. METHODS

4.1 Aerial survey specifications

The 2006 monitoring took place in the form of aerial surveys conducted at approximately fortnightly intervals throughout the summer months (dates in Table 2).

As in previous surveys from 2002-2005, the aerial surveys were undertaken by Air Images Ltd using a Cessna 150 aerobat aircraft, flying at a height of approximately 300m and at a speed of 148 km hr^{-1} (80 knots) (Plate 1). A series of photographs were taken with a Canon EOS-1Ds Mark II digital camera held out of the side window. Various lenses were used, depending on the angle at which the photographs were taken. Positioning was judged on a purely visual basis, due to the natural variation in the position of the Sands. The intervals between surveys varied, although only one survey, scheduled for the second half of May, was missed due to weather conditions. There was also a large gap between the last two surveys, also due to weather issues, which meant that the last visit of 2006 (conducted 21st October) was classified as a winter survey.

Plate 1. Aerial survey of Scroby Sands.

Table 2. Dates, times and coordinates (WGS84 decimal degrees) associated with the winter (W) 2005 and summer (S) 2006 aerial survey programme.

Survey number	Date	Start time	Low water	Location on Scroby	Eastings	Northings
W1	17th November	1350	1518	S point	1.7967333	52.609867
				mid point	1.7874000	52.604550
				N point	1.7864167	52.588617
W2	10th December	1430	1631	S point	1.7997667	52.622817
				mid point	1.7864333	52.598200
				N point	1.7892500	52.605683
S1	16th May	1728	1744	S point	1.7843000	52.608600
				mid point	1.7875500	52.602083
				N point	1.7901000	52.609450
S2	8th June	1410	1303	S point	1.7836167	52.591367
				mid point	1.7873667	52.604983
				N point	1.7905167	52.609500
S3	22nd June	1242	1250	S point	1.7876500	52.589933
				mid point	1.7876500	52.606967
				N point	1.7913500	52.607383
S4	30th June	1850	1855	S point	1.7954500	52.585267
				mid point	1.7973000	52.590450
				N point	1.7908667	52.608650
S5	03 July	2024	2111	S point	1.7852667	52.593217
				mid point	1.7982500	52.604550
				N point	1.7912000	52.608783
S6	7th July	1307	1215	S point	1.7873167	52.586167
				mid point	1.7978667	52.605283
				N point	1.7909167	52.609717
S7	10th July	1432	1504	S point	1.7889667	52.599783
				mid point	1.7966667	52.606183
				N point	1.7916333	52.610300
S8	26th July	1550	1635	S point	1.7875833	52.588167
				mid point	1.7951833	52.606400
				N point	1.7908333	52.609483
S9	5th August	1138	1137	S point	not provided	
				mid point		
				N point		
S10	29th August	1751	1852	S point	not provided	
				mid point		
				N point		
S11	21st October	1456	1508	S point	not provided	
				mid point		
				N point		

Surveys were conducted at low water, when the sandbank was most visible and the greatest number of seals was present (Table 2). The only exceptions to this were the two winter surveys carried out on 17th November and 10th December 2005.

Photographs were supplied to ECON as both 20 cm x 15cm prints, and as jpegs scanned in at 300 dpi and 600 dpi for enlargements showing the seals. These photographs were pieced together to form an aerial map of Scroby, onto which seal locations could be mapped. Approximate GPS points of the exposed sandbank were also taken (a north, middle and south point) so that the haul-out sites could be related to a definable physical area. Aerial overviews of the whole site, including both the sandbars and the wind farm site itself, were also included as a matter of course.

4.2 Analysis of data from aerial surveys

4.2.1 Abundance

The seals were identified and classified using the criteria described in the 2002 report; namely size, body shape, muzzle shape, colour and haul-out pattern. Identification was carried out on the electronic files using the zoom function on Adobe Photoshop. Once identified, each seal was then marked with an identification colour code as shown in Table 3. A break down of seal counts from each of the 11 surveys carried out in winter 2005/summer 2006 are included as Appendix I and plotted in Figure 1 (D & E).

Table 3. Colour codes used in classification of seals. Greys seals were identified with reference to their sex and age divided between adults and young-of-the-year (YOY). Harbour seals were only separated between adults and pups.

Classification	Colour code
Harbour seal adult	Yellow
Harbour seal pup	Orange
Grey bull seal	Pink
Grey cow seal	Light blue
Grey YOY	Red
Unidentified	Purple

The purpose of winter surveys (shown in italics in Appendix I), which were not carried out consistently as part of the monitoring programme, was to simply confirm or disprove the theory of low usage at this time of year (Grey seals potentially being on their breeding beaches). Low usage was confirmed and therefore winter surveys were treated separately from spring, autumn and summer surveys when counts were much higher. The results of winter surveys were thus not used in any statistical tests or calculations.

The total number of seals and the number of each species present was compared between years using non-parametric Kruskal-Wallis tests, with any change in the proportions of different species assessed using Chi-square tests.

4.2.2 Breeding success

Pup counts can provide an index of colony productivity, and therefore represent an important means of detecting change. However, due to the high inter-annual variation associated with haul out counts, as many surveys as possible are required during the pupping period to best measure numbers (Thompson & Harwood 1990). It was therefore recommended that additional surveys be undertaken during the peak Harbour seal pupping period in late June/early July after the initial assessment of data (ECON 2004b). Two, three, and two additional surveys were completed in 2004 to 2006 respectively.

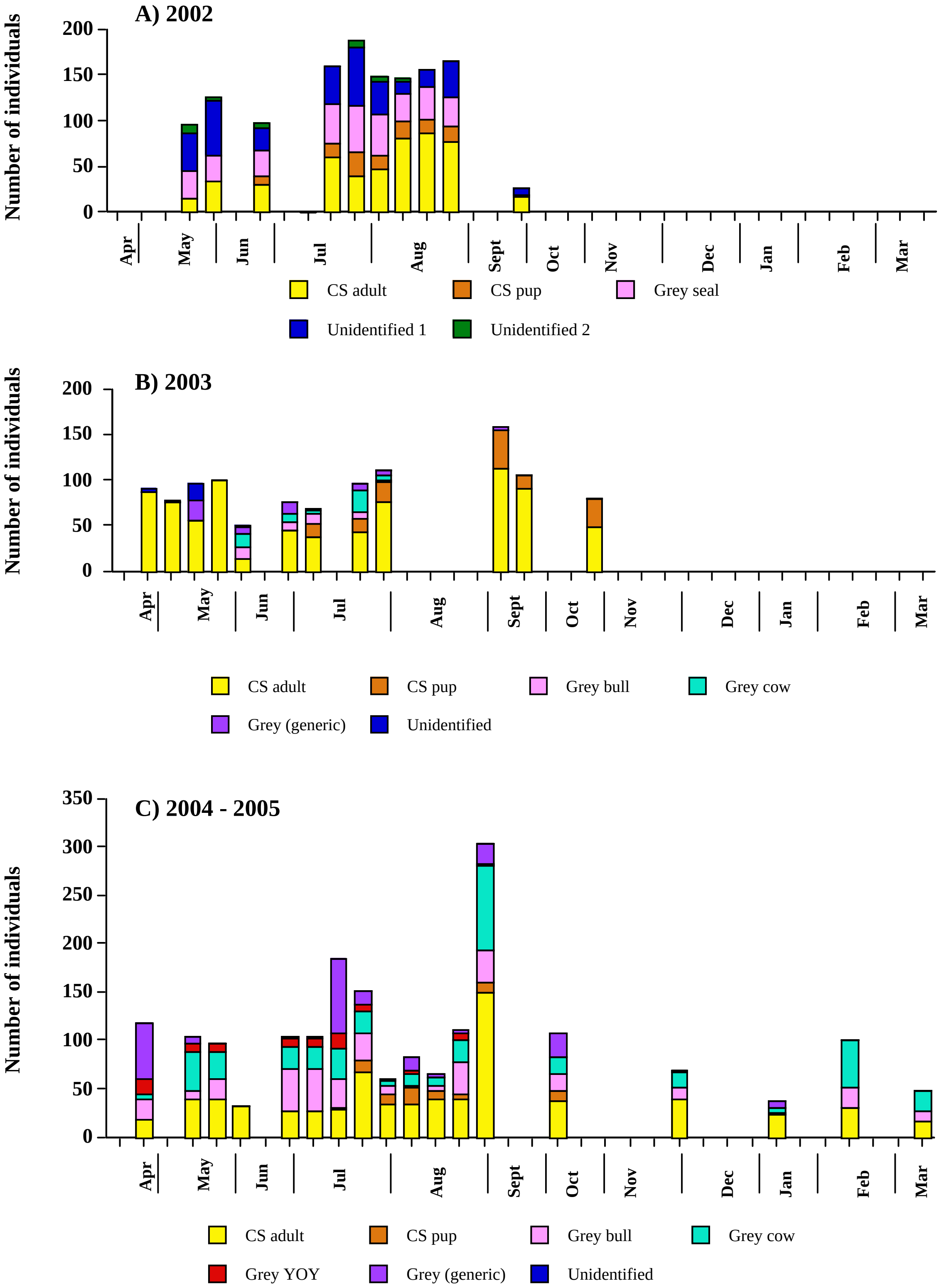
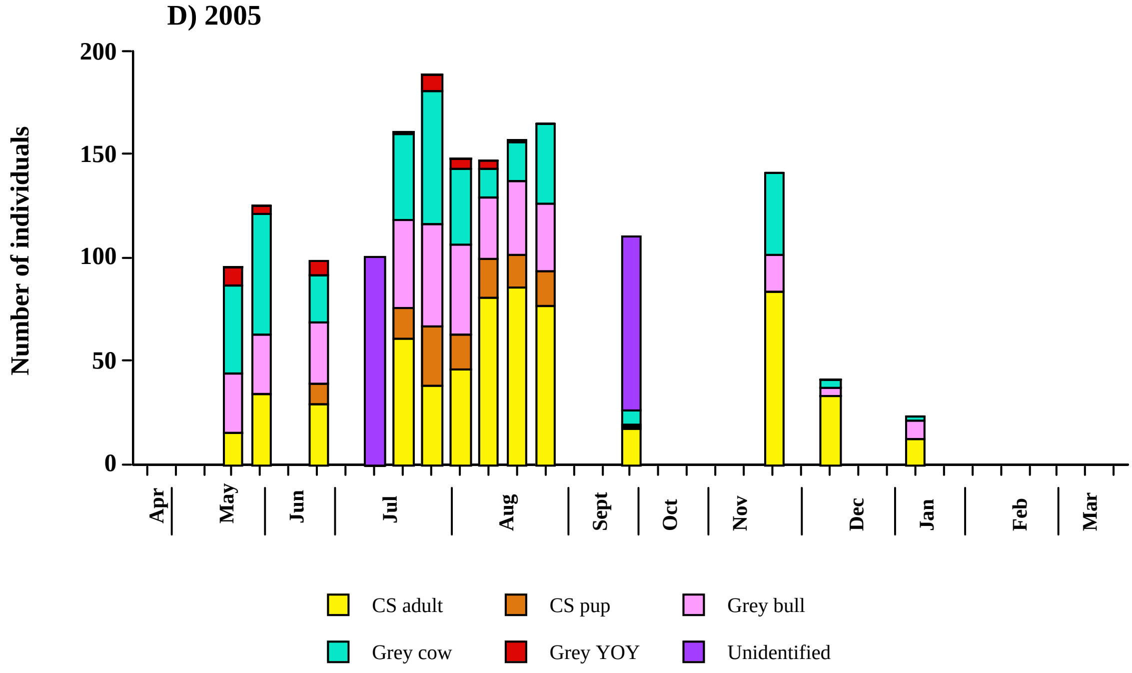


Figure 1. The number of Harbour (CS), Grey and unidentified seals including different sex/age groups hauled out on Scroby Sands in A) 2002, B) 2003 and C) 2004 (2005 and 2006 overleaf).



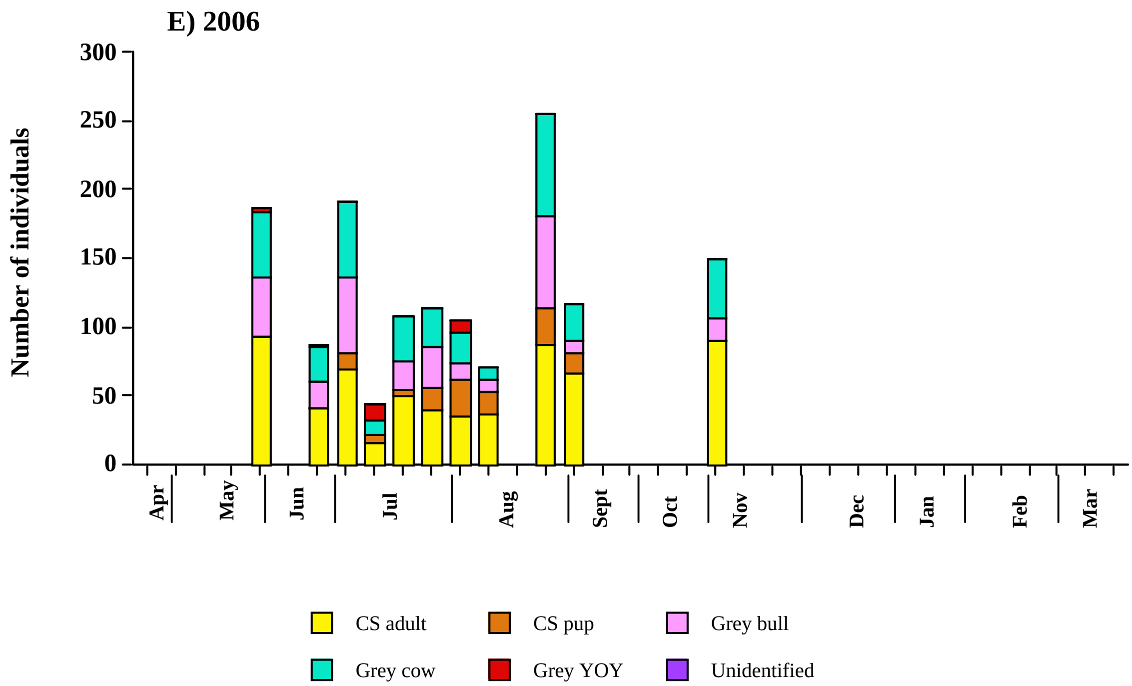


Figure 1 (cont'd). The number of Harbour (CS), Grey and unidentified seals including different sex/age groups hauled out on Scroby Sands in D) 2005 and E) 2006 (2002, 2003 and 2004 previous page).

Pup productivity was assessed by using all surveys after pups first appeared, which was typically early June with the exception of 25th May in 2002, until August, after which early born pups could not be safely distinguished from adults on size, shape and behavioural association. Non-parametric Kruskal-Wallis tests were then used to test for inter-annual differences in the dataset of 34 surveys over the 5-year period. Breeding success was also assessed more subjectively using a combination of peak, mean and median pup counts.

4.2.3 Distribution

In order to map the distribution of seal haul out areas the best photographic sequence was selected (i.e. the most complete, taken in the best light and containing the maximum number of seals). This was then traced onto graph paper and the location of seals mapped. These haul-out groups were matched with the enlargements provided for species identification so that the types of seals in each group could be labelled. Maps showing the number and location of these seals are included as Appendix II.

5. RESULTS

5.1 Abundance and species composition of seals

The total number of seals hauling out on Scroby Sands between years was statistically significantly different, although post-hoc comparisons did not detect a significant difference between a particular year and any other (Table 4). This was despite relatively little variation in mean and median values, relative to range within a season (Table 5).

Table 4. Results of Kruskal-Wallis tests for inter-annual differences in the numbers of seals of different species and type from 2002-2006. The number of samples (*n*) in different years, total *n*, degrees of freedom (df), H statistic, probability and location of differences (post-hoc test) are shown.

Test description	*n* and total *n* (2002-2006 inclusive)	df	H	Probability	Location of differences
Total number of seals	10, 12, 15, 13, 11= 61	4	10.91	0.028	None
Harbour seals	10, 12, 15, 13, 11 = 61	4	15.16	0.004	2002>2004
Harbour seal pups	7, 6, 6, 7, 8 = 34	4	8.80	0.066	-
Grey seals	10, 12, 15, 13, 11 = 61	4	19.66	0.001	2002<2005 2003<2004, 2005 & 2006

A Chi-square test showed that the proportions of Harbour to Grey seals varied significantly ($p<0.001$) with the difference lying between the baseline years and 2004 (Table 6). Further partitioned datasets clearly illustrated that the baseline years were highly significantly different from the construction and operation years (Table 7), with the construction year operating as a watershed for the significant underlying shift from a preponderance of Harbour seals (4-5:1) in 2002 and 2003 to equality (1:1) of the two seal species in subsequent years (Table 5).

5.2 Abundance of Harbour seals

In accordance with the shift in species composition there was a significant differences in the numbers of Harbour seals between years (Kruskal-Wallis test, n=61, H =15.16, df=4, $p<0.01$). A post-hoc comparison revealed significantly ($p<0.05$) lower Harbour seal numbers in 2004 compared to 2002 (Table 4). Counts of Harbour seals from 2006 were relatively similar to those obtained in 2005, suggestive of a post-2004 population recovery.

Table 5. Summary statistics (mean, median and maximum values) of measures of seal haul-out counts in all years[3], where *n*=number of surveys, and n_p=number of surveys in the pupping period.

Parameter	Measure	Year & number of samples				
		2002 *n*=10 n_p=7	2003 *n*=12 n_p=6	2004 *n*=15 n_p=6	2005 *n*=13 n_p=7	2006 *n*=11 n_p=8
Total numbers of seals	Mean	141	96	108	138	129
	Median	147	94	101	145	114
	Maximum	203	159	304	189	255
	Minimum	76	66	33	96	33
Harbour seal numbers	Mean	107	82	52	59	66
	Median	87	80	48	67	63
	Maximum	191	155	161	102	114
Harbour seal productivity (pup counts)	Maximum	67	42	16	28	28
	Median	12	19.5	6	16	15.5
	Mean	17.4	22.8	6.7	15	15.4
Grey seal numbers	Mean	22	15	52	64	61
	Median	0	8	58	71	54
	Maximum	98	51	143	122	141
Species composition	Harbour/Grey ratio	4.94	5.64	1.01	0.93	1.12

Table 6. Chi-Square test for species composition change in seals hauling out at Scroby Sands. Actual (total numbers in a season) and expected values assuming a constant distribution are shown.

Year	Actual values (totals)			Expected values		df	X^2	Significance
	Harbour	Grey	Total	Harbour	Grey			
2002	914	216	1130	789.6312	340.3688	4	869.40	<0.001
2003	959	112	1071	748.4027	322.5973			
2004	723	791	1514	1057.966	456.0339			
2005	614	777	1391	874.483	516.517			
2006	752	671	1423	863.521	559.479			
Totals	3210	1896	5106	3210	1896			

Table 7. Results of partitioned Chi-Square tests illustrating the timing of changes in species composition of seals hauled out on Scroby Sands.

Description of comparison	df	X^2	Critical value	Significance
Baseline (2002 & 2003) vs construction (2004)	1	298.30	3.84	<0.001
Baseline (2002 & 2003) vs operation (2005 & 2006)	1	535.94	3.84	<0.001
Operation (2005 & 2006) vs construction (2004)	1	0.05	3.84	ns
Construction (2004) vs all other years (2002, 2003, 2005, 2006)	1	138.00	3.84	<0.001

[3] The data differs slightly from similar tables presented in 2002-2004 monitoring reports due to the decision to include pups in overall Harbour seal numbers. In earlier reports it was decided to exclude pup counts on the grounds that they were having a disproportionate influence on counts. The use of a now much larger database means that their exclusion is no longer necessary. Thus all young seals (Grey and Harbour) are included in this final analysis.

Peak counts represent the best indicator of pupping success, because they indisputably show that a certain number of pups have been born. However, they are problematic in that unless surveys are carried out daily, there is a relatively high risk that the site will not be surveyed on the occasion when peak counts are present, especially since pupping has the potential to take place within a relatively short, and unpredictable, time window. A subtle shift in the timing of surveys from 2004 to 2006 inclusive, thereby increasing the number of surveys in which pups could be detected (Table 8), was designed to increase the chances of detecting peaks. A lower number of surveys with high variation in baseline years (2002 and 2003) may ultimately have been responsible for the lack of detectable inter-annual differences in Harbour seal pup numbers (Kruskal-Wallis test, *n*=34, H =8.8, df=4, p=0.066 –Table 4), although the numbers of pups broadly mirrors the number of adults present.

Table 8. Mean, median and peak Harbour seal pup counts from all years, described characteristics of the season and a relative assessment of success.

Year	Mean	Median	Peak	Description	Relative assessment
2002 *n*=7	17.4	12	67	Short pupping period with a very high peak	Highly productive season
2003 *n*=6	22.8	19.5	42	A lower peak, but high median and mean value	Successful (at least) season
2004 *n*=6	6.7	6	16	Poor mean, median and peak values	Poor season
2005 *n*=7	15	16	28	A low peak, but high mean and median values.	Moderately successful season
2006 *n*=8	15.4	15.5	28	A low peak, but high mean and median values.	Moderately successful season

Despite the lack of a significant difference between pup numbers between years, a more subjective evaluation of pupping success based on mean, median and peak counts does suggest ecologically meaningful differences in breeding success between years (Table 8). Mean counts were generally lower than medians, on account of the fact that the former can be influenced by variance in counts such as the occasions when a lot of seals (including pups which actively swim within hours of birth – Anderson 1991) are at sea. The similarity of median values throughout all years, with the exception of 2004, indicates that the number of pups observed during surveys in the area was generally consistent between years, although higher mean and peak values in the 2002 and 2003 suggest that more pups were actually born in these years than in 2004, 2005 and 2006. Low mean, median and peak values in 2004 strongly indicate that pupping was poor, whilst stable means and medians in 2005 and 2006, which are strikingly similar, may be best described as moderate years (Table 8).

5.3 Abundance of Grey seals

Counts of Grey seals hauled out were significantly different between years (Kruskal-Wallis test, *n*=61, H =19.66, df=4, p=0.001 –Table 4). Post-hoc tests revealed counts were significantly greater in 2004-2006 than in 2003, indicative of a 'step-up' in numbers between 2003 and 2004, the year of construction. A significant difference in counts between 2002 and 2005 provided further evidence of a difference in population size between the baseline (2002 and 2003) and years of construction (2004) and operation (2005 and 2006).

Mean counts clearly indicate the stepped change with the numbers of Grey seals increasing by 2-4 fold from the baseline to construction/operation. Median and maximum counts illustrate the generally low, but variable numbers in the baseline years. In 2002 for example, whilst the median value was 0, a maximum count of 98 was made on both 1st and 16th September at the end of the monitoring programme triggering the recommendation for winter surveys in order to ascertain whether Scroby was acting as an important pre-breeding assemblage site, or was even still in use as a breeding ground. During and after construction, maximum values consistently reached >120 animals, representing at least a 2.4 fold increase from the lowest value in the baseline year. Median values also increased considerably and were relatively consistent between years illustrating a tendency for greater frequency of occupation of the Sands by Grey seals. The slightly lower median count in 2006 is likely to be heavily influenced by two surveys during which few Grey seals were present (Survey 4 -30th June and Survey 8 – 25th July). Some irregularity of use of haul-out sites by Grey seals in the summer is to be expected, since at this time of the year populations are transient, congregating wherever prey supplies are greatest in order to accumulate the necessary resources required for breeding (Hewer 1974).

5.4 Haul-out distribution and habitat change

In order to assess whether the haul-out distribution of seals had changed between years, the frequency occurrence of seals in different areas was mapped (Figure 2). During 2002, when Harbour seals were the more abundant of the two species, these hauled out in a range of locations during the season, but with greater frequency on the more exposed seaward edge of the Sands. This pattern had changed somewhat by 2003, with far greater frequency of use of the more sheltered (landward) north-western side (ECON 2004b).

Harbour seals continued to use this area in 2004 and the subsidiary sand bar which had started to form the year earlier (P. Lines, Enviroserve, *pers. comm.*), with the now more numerous Grey seals tending to focus on the southerly end and highest point of the Sands. The additional sandbank area for seal haul-out through the formation of the subsidiary sandbar was perceived to be of considerable benefit in that it both provided an extra haul-out site, and sheltered the western side of Scroby (ECON 2004a). However, the subsidiary sand bar appeared to be abandoned during 2005, with not a single seal observed there during surveys. The relatively few Harbour seals observed tended to favour the sheltered south-western side although they also occurred in mixed haul-outs with Grey seals, which were heavily focussed on the southern end of Scroby Sands. This coincided with the permanent exposure of this highest point for the first time in nearly 40 years and even at high water a small group of seals could be observed hauled out there (*pers. obs.*).

A)

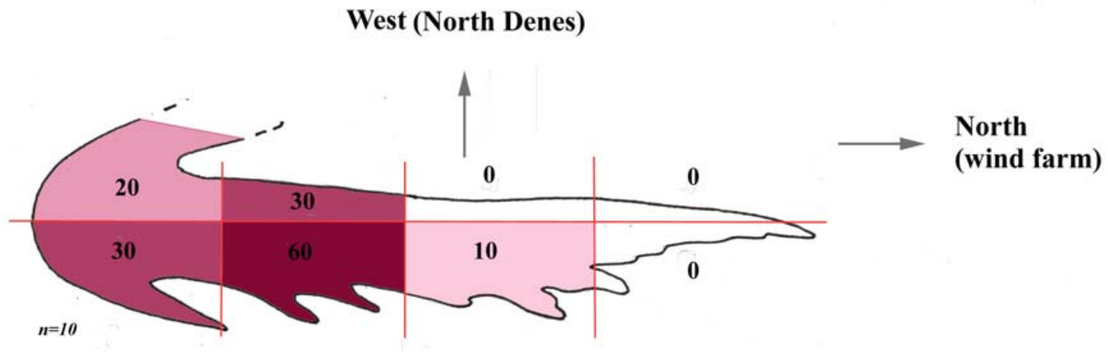


Figure 2. Frequency of occurrence (% of surveys) of seals in each area in A) 2002 (above) and B) 2003, C) 2004, D) 2005 and E) 2006 (overleaf).

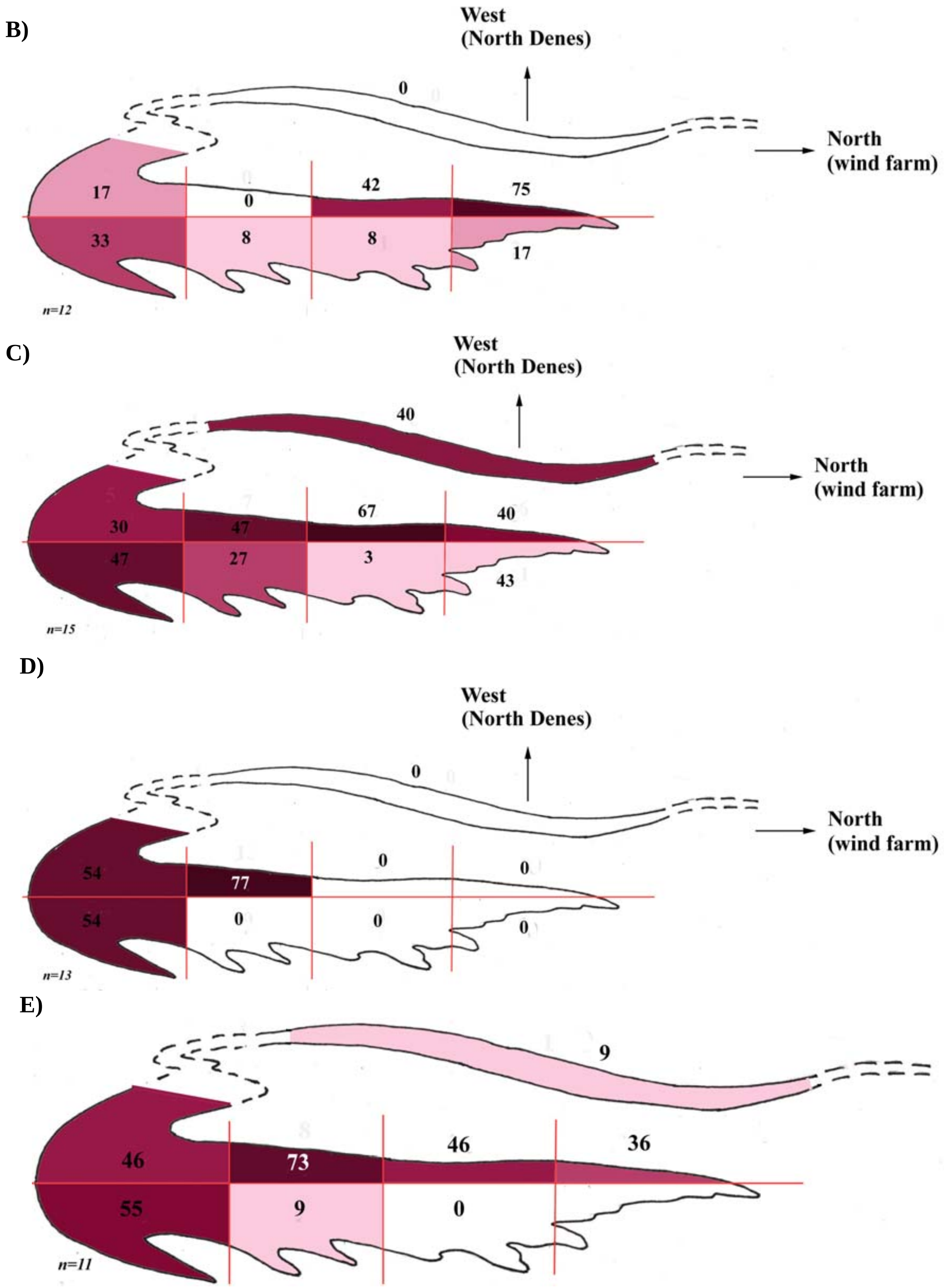


Figure 2 cont'd. Frequency with which seals occurred in each area by survey in A) 2002 (previous page) and B) 2003, C) 2004, D) 2005 and E) 2006 (above).

Plots of the three outline GPS points taken by Air Images during seal surveys showed that there was considerable variation in the length of sandbank exposed at low water (Figure 3), which meant there was no significant change of length from 2004 onwards (Kruskal-Wallis test, n=33, df=2, H=0.77, p=0.68). Nonetheless, mean, median, and maximum lengths of Scroby between years were all greater in 2005 than in 2004 and 2006 (Table 9), mirroring the permanent exposure of the southern point. The physical location of Scroby also appeared to shift in this period, with movement primarily to the south in 2005 and to the east in 2006.

Table 9. Mean, median and peak length of Scroby in 2004, 2005 and 2006.

Length of Scroby (km)	2004 *n*=13	2005 *n*=12	2006 *n*=8
Mean length (± SE)	1.887 (0.218)	2.376 (0.324)	1.848 (0.315)
Median length	2.025	3.933	2.119
Maximum length	2.983	4.332	2.916
Minimum length	0.791	0.948	0.153
Range	2.192	3.384	2.763

The haul out areas used in 2006 represented something of a reversal of the pattern of concentration observed in 2005, although this was largely caused by changes in the distribution of Harbour seals, as Grey seals continued to focus on the southern point (Figure 2). In 2006, Harbour seals occurred throughout the length of the western (landward) edge of the Sands, with isolated use of the subsidiary sand bar once again. Although again as throughout the monitoring period, haul-outs were often mixed, the more dispersed pattern may have been related to pupping Harbour cows, which either haul out together away from the other seals or sometimes haul-out alone (Appendix II surveys 3rd, 7th & 10th July 2006).

6. DISCUSSION

The following discussion focuses on, and is structured by, a number of themes:

- Evaluation of the value (strengths and limitations) of the monitoring programme at Scroby Sands particularly in relation to FEPA license conditions.
- Assessment of population (from haul-out counts) trends of both Harbour and Grey seals at Scroby Sands.
- Determination of whether trends at Scroby were linked to the construction and/or operation of the wind farm or attributable to other factors.
- Interpretation was to be aided by experiences from other sites both onshore and offshore associated with local populations of seals including haul-outs.

This naturally led to a number of conclusions being drawn and recommendations made, which are presented in the following section.

6.1 Evaluation of the monitoring programme

The Scroby monitoring programme fulfilled and exceeded the FEPA licence requirements as a result of the addition of a further year's data with additional specific surveys both in the Harbour seal pupping period and winter period responding to a specific need for further information. In summary, notable achievements were:

- A grand total of 67 regular aerial surveys over the five years of baseline, construction and operational monitoring periods.
- Robust data regarding the number and species of seals using the site throughout the year.
- Increased intensity of surveys over the breeding period to inform assessment of colony productivity.

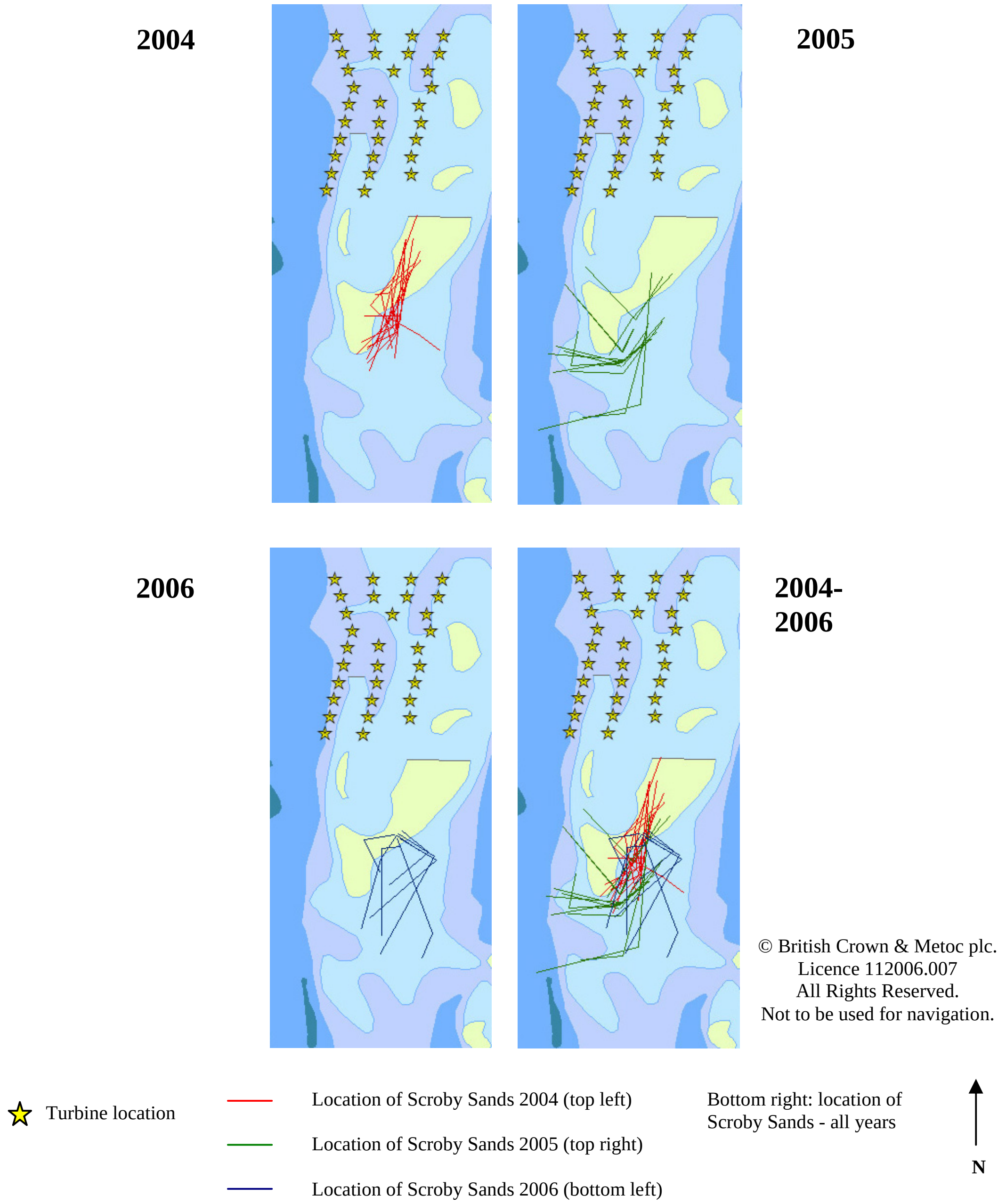


Figure 3. Location of the main exposed sandbank, as recorded by Air Images during aerial seal surveys conducted from 2004 to 2006.

The result is a dataset that thoroughly documents seal use of Scroby Sands over the past five years, enabling further understanding of the nature of the significant population changes that have occurred in both species during this period. Nonetheless, comparison with other wind farm sites at which seals were an important target of ecological impact assessment, such as Bockstigen in Gotland, Sweden (Box 1) and Nysted (Box 2) and Horns Rev (Reef) (Box 3) in Denmark suggest a number of generic limitations of using aerial surveys of haul-out counts include:

- Aerial surveys as a single technique can only enable detection of (relatively gross) changes in number. Potential reasons for any changes observed remain speculative unless targeted work is undertaken to investigate them.
- Other factors that might influence haul-out counts (and which may be site specific) needs to be investigated, otherwise data cannot be corrected for the effects of influential environmental variables (e.g. wind speed/direction, season, time of day).
- If the haul-out area is not contained within the wind farm, it is not possible to assess whether seals are displaced from the actual turbine array or whether they continue to pass through it, or even forage within it.
- No direct knowledge of how the seals respond to disturbance is gained from flyover surveys of haul-outs. Flush experiments, such as those carried out at Bockstigen (Box 1), or observational monitoring could inform which activities invoke definable responses. These are likely to be site-specific driven by how habituated the seals are to human activity.

With the benefit of hindsight, an obvious limitation of the dataset and thus the FEPA license conditions in general, was the lack of monitoring during pile driving, the activity most likely to result in significant impacts (see 6.2 below). Aerial surveys would have provided some idea of the extent and duration of any effect, although clearly, relatively low-cost observational work (by human observers or cameras akin to the situation at Bockstigen - Box 1), to directly measure the extent and duration of any response to the impacts of disturbance during construction particularly would have been greatly beneficial.

More expensive techniques such as satellite telemetry (see Boxes 2 & 3) in combination with aerial surveys have the potential to provide conclusive proof if seal behaviour and habitat use at sea changes significantly. However, disadvantages associated with this technique other than high cost, include the relatively small number of fixes (mean of 3.6 fixes per day – Dietz *et al.* 2003) and their bias towards haul out sites (Box 3). There is also the risk, that as was the case at Horns Rev, that if the seals do not use the wind farm site to begin with, then impacts are not going to be detectable, although this may provide valuable information in itself because it indicates that the area is not of specific value to seals.

As a relatively small site (3.46 km^2) Scroby Sands was thus highly unlikely to contribute significantly to the large foraging range of both species and especially Grey seals, which can have home ranges in the order of 1,000-6,000 km^2 (Sjöberg & Ball 2000). There was thus no justification for the inclusion of satellite tracking within the monitoring programme of this small single site. However, in view of the ability of both species to travel large distances on foraging trips (e.g. 45 km for Harbour seal – Thompson & Miller 1990, and anything up to 2,100 km for Grey seal – McConnell *et al.* 1999), thereby potentially including the numerous, larger (Round 2) developments planned elsewhere (e.g. Greater Wash and Thames), it is plausible that Scroby Sands could contribute to a significant cumulative wider impact. Any assessment of cumulative use would then only be possible through individual recognition at the very least and more specifically through individual-based tracking.

Box 1. Bockstigen Offshore Wind Farm, Gotland, Sweden

Site details:

- Constructed 1997.
- 5 x 2.5 MW turbines.
- Data on seals collected pre-, during, and post construction (1996, 1997, 1998 & 1999).
- Located near two Grey seal haul out sites.

Monitoring programme:

Regular counts were carried out 2 hours after sunrise three times a week, in accordance with the methodology specified by the Swedish Museum of Natural History. Extended behavioural observations were also made during the month long period from June 10th to July 10th 1999. Tests were also carried out to assess disturbance of seals, both in association with the actual operation of the wind farm (using the number of turbines in operation as a measure of operational activity), and also associated with the presence of boats and their distance from the seals. Several meteorological datasets were also gathered in order to examine the effects of local weather conditions (especially wind speed and wind direction) on haul out counts. Water level data was also obtained. The effects of these variables were corrected for in the final analysis.

Results to date:

Whilst the results showed considerable variation in seal counts over the years, overlying a general trend of decline, it was unclear whether this variation was associated with the construction and/or operation of the wind farm. Whilst there was some strong evidence that the seals were temporarily affected by the increase in human activity associated with construction, the possibility that the turbines themselves were affecting the seals appeared weak. This latter statement is reinforced by the observation that the seals moved from their initial favoured haul out site to a second site that was actually nearer the turbines. The main problems in assessing the situation appeared to be a lack of long-term data and the lack of a suitable control site, meaning that it was hard to put the decline of this small colony of long-lived and highly mobile seals into wider local and regional contexts. However, direct observations of seals flushing in response to boats associated with service and maintenance indicates that seals are sensitive to the increased levels of human activity, although recovery time (time taken for seals to haul out again) was usually short. It was concluded that the frequency of such disturbance events is likely to be a particularly important factor in determining the ultimate value of a haul out site.

Reports:

Sundberg, J., & Søderman, M. (2000).

Website:

http://www.vindenergi.org/Vindforskrapporter/Grasal_sundberg.pdf

Box 2. Nysted Offshore Wind Farm, Denmark

Site details:

- 72 turbine development located 4 km south of Nysted and 13 km west of Gedser, completed 2003-2004.
- 4 km SW of the most important Harbour seal haul out and breeding site in the western Baltic sea (Rødsand Seal Sanctuary, protected from all access to within 500 m from 1 March – 30 September).
- Site estimated to be used by c.250 Harbour seals and 25 Grey seals.
- The impacts of wind farm construction & operation on seals was monitored by NERI (National Environmental Research Institute, Denmark) using a combination of remote video monitoring, aerial surveys and satellite telemetry.

Monitoring programme:

- Aerial surveys of local haul out sites to test for differences in the use of the seal sanctuary during and after the construction of the wind farm.
- A remote controlled camera system mounted on a 6m high tower to monitor the main site throughout the day with photos being taken every five seconds. (The installation and presence of the camera had no observable effects on usage of the haul out site by seals). Year round monitoring undertaken to assess seasonal variation and to allow data to be gathered on other significant factors, e.g. the time of day, wind speed and wind direction. The limitations of the camera and the clustered nature of seal haul outs meant that it was frequently not possible to count the seals when >20 were present, and so photographs classified grouped into the following categories (0, 1-5, 6-10, 11-15, 16-10 and >20 seals).
- Six Grey seals and four Harbour seals were tagged with satellite transmitters, and fixes on the animals were taken from both land and sea in order to assess to what extent the wind farm site was used by seals.

Results to date:

1) Aerial surveys – results not yet available.

Throughout the monitoring period (2002-2005), the population increased by 17% following the PDV outbreak. During this period, no significant effects of construction or operation were statistically detectable, although there was a slight (but not significant) decrease in the relative importance of the Rødsand seal sanctuary during the construction period.

2) Remote video monitoring

Haul out counts increased between the baseline years and the construction year by 12.5%, reflecting general population recovery following a fall in numbers associated with the 2002 PDV outbreak. The only exception to this trend was during pile driving when reductions of 31-60% occurred (note that that these figures have been corrected to allow for the influences of seasonal variation, variation associated with time of day, and differing wind speeds and directions). Since seal scrammers and porpoise pingers were used prior to drilling it is not known whether the reduction in haul out counts was due to the effects of these devices or to the drilling itself. It is also not known whether the seals remained in the area without hauling out, or left the area to haul out elsewhere.

The general presence of the wind farm had no discernible effect on seal haul out counts.

3) Satellite telemetry

Although the study was limited to a few individuals, the data showed that:

- Grey seals had a far larger home range than expected (average 51,221 km^2).
- Harbour seals had a substantially smaller home range (average 394 km^2) than Greys concentrated around a specialized near-shore feeding area.

Therefore the Rødsand area was identified as being more important for Harbour seals than for Grey seals, which had alternative feeding and haul out sites which they used for the major portion of the year. Although only a few (seven) positions were obtained within the wind farm area, the calculated Kernel home range of all four Harbour seals and four out of six tagged Grey seals extended into the wind farm area. However, the small number of fixes from within the wind farm area meant that the information gathered was not sufficient to allow for a detailed study into the effects of construction.

Summary:

Wind farm construction and operation had no detectable impacts on seals. The report highlights the need for the potential benefits of artificial reef formation around turbine bases to be investigated.

Reports:

Edrén, S.M.C., Teilmann, J., Dietz, R., Cartensen, J. (2004).
Dietz, R., Teilmann, J., Henriksen, O.D. & Laidre, K. (2003).
Tielmann, J., Carstensen, J., Dietz, R., Edrén, S.M.C. & Andersen, S.M. (2006).
Tougaard, S., & Tougaard, J. (2003).

Websites:

http://uk.nystedhavmoellepark.dk
http://www2.dmu.dk/1_om_dmu/2_afdelinger/3_am/4_expertise/5_research/6_windmill/

Box 3. Horns Rev

Site details

- 80 turbine 160 MW site situated 14-20 km off the coast of Jutland, Denmark.
- Construction completed in 2002.
- Based on previous VHF radio telemetry studies it was assumed that the wind farm area was located on a central foraging area for seals in the Danish Wadden Sea.
- Harbour seals are the dominant species although Grey seals also occur.

Monitoring Programme:

The monitoring programme consisted of satellite telemetry carried out on 10 Harbour seals. The work was originally planned as baseline study, but tagging was delayed and the period of data collection in 2002 overlapped with construction. It was then anticipated that the study might enable some assessment of whether the seals avoided the wind farm area during construction.

Results to date:

There were so few fixes from the wind farm area both during the baseline and the construction periods that assessing the impacts of construction was not possible.

The results of the study revealed that the Harbour seals around Horns Rev travelled over considerably larger distances than the Harbour seals tagged near Nysted (Box 1), with higher numbers of visits to the German Wadden Sea than had been expected. Although the data revealed substantial variation in foraging behaviour both between seals and for each seal, it also revealed some consistently used foraging routes. Overall, the seals only spent 0.1% of their time in the wind farm area and it was therefore concluded that the site acted rather as a corridor for movements between other foraging areas.

It was recommended in both the studies from Nysted and from Horn's Rev that the new GPS/GSM technique be used to improve the resolution of the data, since satellite telemetry has the disadvantage that in order to get a fix, the transmitter (glued to the seal's head) has to be out of the water several times during a satellite passage (twice a day). This meant that in general fixes were few in water and that the fixes that were obtained were probably biased towards haul out sites. With the GPS/GSM transmitter GPS data is sent via a mobile radio network (GSM) to the user's office potentially resulting in much improved data resolution. However, when the technique was tested on a seal in the Sealarium at the Fisheries and maritime Museum, Esbjerg, the tag remained on the seal for 13 days, during which period only one fix was obtained due to the failure of the unit to connect to the GSM-net. Further work is planned to refine and develop these techniques.

Summary:

Whilst no impacts were detected, the final report concludes that the methods used were not in fact capable of detecting impacts unless they were very strong. Whilst no impacts were detected, the report cautions that it cannot be concluded that there were no effects.

Reports:

Tougaard, S., & Tougaard, J. (2003).
Tougaard, J., Ebbesen, I., Tougaard, S., Jensen, T., and Teilmann, J. (2003).
Tougaard, J., Tougaard, S., Jensen, R.C., Jensen, T., Tielmann, J., Adelung, D., Liebsch, N. & Müller, G. (2006).

Website:

http://www.hornsrev.dk/Engelsk/Miljoeforhold/uk-rapporter.htm

6.2 Cause of change in Harbour seal numbers

Significantly fewer Harbour seals were observed in 2004 than in 2002. Counts from 2005 and 2006 were not significantly different to any of the other years, and lay somewhere between the higher numbers observed in the baseline years (2002 and 2003) and the reduced counts observed during the construction year (2004) (Figure 4). This pattern was tentatively interpreted as representing some recovery in numbers following a notable decline during the year of wind farm construction. Whilst higher mean and peak counts from 2006 (e.g. 114 on 5th August) provides some cause for optimism of further recovery, this is not statistically significant and overall the similarity in counts in 2005 and 2006 counts implies stabilisation rather than the further increases that would be required to bring the population back to the level observed during the baseline years (Figure 4).

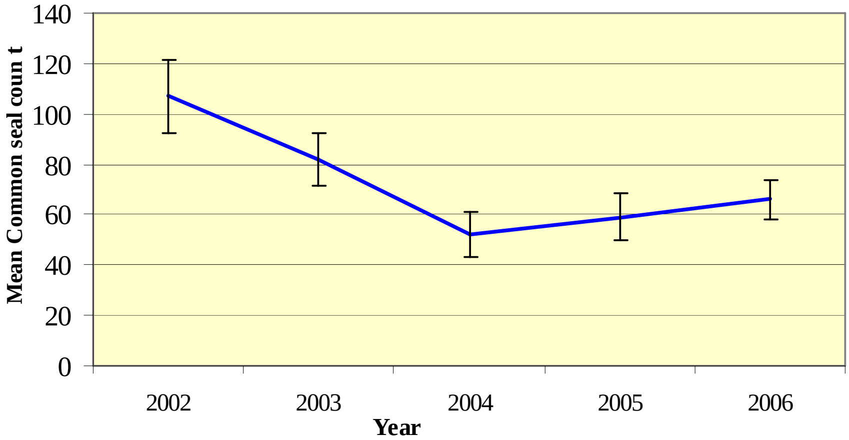


Figure 4. Mean (±1SE) Harbour seal counts from 2002-2006.

The large difference in maximum counts of pups between the different years mirrors the general trend in adults with 2002 and 2003 classed as successful seasons, 2004 as a very poor season and 2005 and 2006 being moderately successful seasons. Yearling seals are effectively indistinguishable from adults in aerial surveys although female seals are not sexually mature until 3-4 years of age with males being 5-6 (Anderson 1991). Consequently, recruitment of seals born in 2002 and 2003 could add to the number of apparent adults in haul-out counts after 2004 with females also conceivably contributing to an increasing number of pups by giving birth themselves.

The key question remains whether a decline in Harbour seal numbers in 2004 was caused by the construction of the wind farm or whether this was coincidentally linked to other factors as part of a wider trend? Certainly, the potential for a construction-related impact was recognised in the report forming part of the Environmental Statement for the Scroby Sands OWF (Harwood 2001). Underwater noise is intuitively the most likely element of construction to generate an impact on the behaviour and thus distribution and abundance of marine mammals.

Nedwell & Howell (2004) suggested monopile foundation installation through pile driving was typically the noisiest activity associated with wind farms, generating Source Levels of 215 dB re 1µPa @ 1m, although dredging (suction and hopper dredgers) may reach a peak spectral source level of 177 dB re 1µPa @ 1m at 80-200 Hz, whilst even a 25m tug pulling an empty barge has been reported to have a 170 dB re 1µPa @ 1m Source Level.

In more detail, Thomsen *et al*. (2006) concluded that for Harbour seals the zone of audibility for pile-driving will almost certainly extend well beyond 80 km, perhaps even hundreds of kilometres from the source. Behavioural responses such as disturbance, flushing and displacement from the area are thought possible over large distances, perhaps up to 20 km. On a regulatory basis, hearing loss was of concern within a zone of 400 m with the potential for severe injuries (most likely resulting in death) in the immediate vicinity of pile-driving. On this basis, it seems inevitable that Harbour seals were at least entirely displaced from the haul-out from <1.5 km to a maximum of 7 km from the wind farm (depending on the location of the haul-out and location of works within the wind farm) during periods of pile-driving.

Unfortunately, no monitoring of seals by any means was undertaken during pile driving, which took place over the winter of 2003/4. However anecdotal evidence from local fishermen suggests that both Harbour and Grey seals left the area, with many heading south into Suffolk, where large numbers were reported associating with fishermens' nets at Southwold. Summer surveys suggested a proportion of the Harbour seals (or perhaps seals new to the area) returned at some time in the period after pile driving had finished, it appears that a proportion of the seals comprising the colony did not, perhaps choosing to haul out elsewhere (e.g. Orford Ness in Suffolk, Blakeney Point in North Norfolk or the Wash separating Norfolk and Lincolnshire).

Seal researchers accept that there is considerable individual variation in the response of individuals to disturbance, with some individuals being extremely tolerant to anthropogenic activity, whilst others are extremely intolerant and readily disturbed and displaced (Sophie Brasseur *pers comm*.). This can create the misleading impression that *all* seals are confiding and tolerant of even potentially damaging human activity. Whilst there is also overlap in the response of different species, Grey seals are perhaps more likely to be tolerant and habituate to human presence (boats, divers etc) and activity, than Harbour seal, belying its now accepted common name. Harbour seals are also though more sensitive to disturbance, having slightly better hearing than Greys (Edwards *et al.* 2005). Thus, unlike Harbour seals, Grey seals returned rapidly (and more), even increasing above baseline counts from 2004 onwards (see below).

Whether the continued construction work at Scroby over the summer of 2004 including the completion of turbine construction (nacelle and blade installation using a jack-up barge) (Plate 2) scour protection and inter-array cabling was responsible for the continued absence of Harbour seals remains unknown. Nonetheless, there is clear evidence of a negative correlation between the number of Harbour seals hauled out and the number of boats present at Scroby Sands (as photographed on each aerial survey) using data from all years (Spearman rank correlation, r_s = -0.30, *n*=64, p=0.015). This is not significant using data from within 2004 only (Spearman rank correlation, r_s = -0.48, *n*=13, p=0.09 –Figure 4) in this summer (Figure 5). This is perhaps not surprising from a small dataset with a generally small number of Harbour seals (apart from the 161 on 10th September 2004 after all construction was complete) and given the haul-out count was not corrected for other factors that are known to affect seal haul-out counts, such as wind speed, wind direction and diurnal variation. Such variables are known to be colony specific (Grellier *et al.* 1996) and have not been investigated at Scroby Sands. Moreover, the presence of vessels may not be a direct indicator of construction activity *per se*, and lower counts would indicate a response to other construction activity conducted with only a few vessels present, thereby explaining outliers on Figure 5.

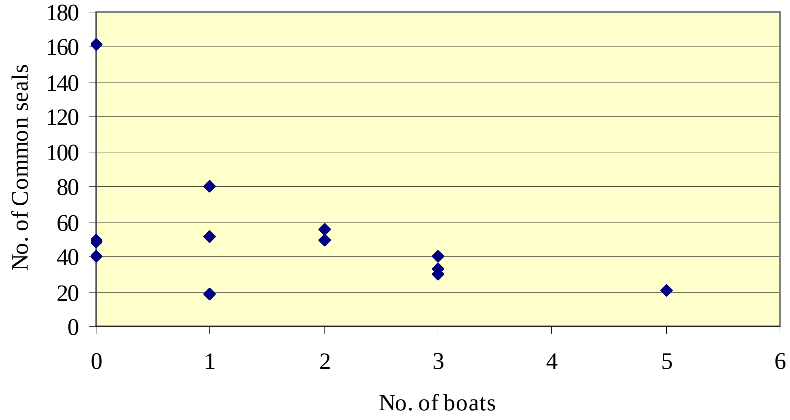


Figure 5. The number of Harbour seals and the number of boats photographed on different occasions during the 2004 (construction) monitoring.

Although seals have also been found to respond to increased vessel traffic during construction works at other wind farm sites, e.g. Bockstigen in Gotland (Sundberg & Söderman 2000), a negative response to vessels was not anticipated to be a major problem at Scroby Sands, since a tourist boat regularly visits the colony promoting habituation to such activity (Harwood 2001). However, it is mostly Grey seals occupying the southern tip of Scroby that are familiar with the vessels involved (including the *Haven Cruiser* sailing from near Britannia Pier), with Harbour seals preferring areas that cannot be readily accessed as a result of sandbars and generally shallow water. It is also possible that seals simply responded unfavourably to unfamiliar boats as has been reported previously (Bonner 1982, Richardson *et al.* 1995).

Whilst there is a plausible mechanism for construction-related disturbance leading to a short-term decline in the numbers of Harbour seals hauling-out on Scroby Sands, there is no evidence that the numbers of pups produced was lower than expected from the number of females, as was suggested in the local (*Great Yarmouth Advertiser* 30th September 2004) and national press at the time (*Daily Mirror* 6th June 2005). This stemmed from claims from the Winterton Seal Sanctuary that an increasing number of young Harbour seals had to be rescued from the beaches, with additional speculation that pups were being born dead and with broken jaws and flippers and females abandoning pups as a result of noisy construction activity or even simply the presence of the operational wind turbines.

There is no evidence for any of these claims and a series of intense summer storms in 2004 provided an alternative explanation for larger than usual numbers of apparently abandoned or injured pups, which also affected other wildlife. For example, during the peak seal pupping period in June over 1,000 Sandwich tern *Sterna sandvicensis* chicks including many large almost fledged birds were found dead in North Norfolk colonies as a result of very poor weather over 19th and 23rd/24th June (NNNS 2005). In such events, newly born seals are undoubtedly vulnerable to separation from their mothers and injury. Considerable mortality of Harbour seal pups from the Scroby colony has been noted previously, for example in 1960 and 1961, with strandings in the latter year occurring as far afield as West Runton, Horsey and Winterton as well as more locally at Caister and Yarmouth South Denes (Appendix III).

Plate 2. Aerial view of the wind-farm under construction with the jack-up barge in position (courtesy of Aerial Images Ltd).

Plate 3. Aerial view of the extent of Scroby Sands and the developing subsidiary sand bars in relation to the functioning wind farm (also seen in Plate 2 above) (courtesy of Aerial Images Ltd).

The fact that Harbour seal numbers have not yet reached baseline levels may be interpreted as a negative response to an operational wind farm. Whilst it is distinctly possible that vessel activity during routine maintenance activity has some continued effect, the use of the same vessels over time which tend to transit some distance from favoured haul-outs partly as a result of the development of further sand-bars (Plates 2 & 3, *pers obs*,) is thought likely to have led to habituation.

Furthermore, a lack of full recovery of numbers may be simply explained by the fact that any seals displaced away from the area may have exceeded the distance at which return is unlikely to occur routinely. In other words, where the distance of displacement is greater than the distance typically travelled during foraging trips. The latter has been suggested as up to 45 km (Thompson & Miller 1990) which is considerably less than the distance of the nearest suitable habitat for Harbour seals (where they currently occur) at Blakeney Point (~80 km), Wash (~120 km) and Orfordness (~60 km). In fact, the only suitable breeding area appears to the Wash. Recovery of baseline haul-out numbers may thus rely on dispersal movements (e.g. of young animals) or recruitment of young animals from within the local population (as suggested above).

Both mechanisms become more unlikely as a result of the known national decline in Harbour seal populations over the past five years (SCOS & SMRU 2006). Some of this is a result of a further outbreak of the Phocine Distemper Virus (PDV) (which decimated Harbour seal populations in the North Sea both in 1988 and again in the winter of 2002 which resulted in an estimated 22% mortality in the Wash (Thompson *et al.* 2005). As a 45% decline in the Wash has occurred over the last years (Figure 6), there are clearly also other factors at work. Other Harbour seal colonies with no known outbreaks have also undergone chronic (40%) decline over the last 5 years. These include Orkney, Shetland, and the Firth of Tay (Lonergan *et al.* 2007). The geographical extent of the colonies affected by these chronic declines indicates that the causative factor(s), which as yet remain unexplained, affect Harbour seals over a wide area of the North Sea. Such reasons could include reduced fertility following the PDV outbreak, or increased competition from Grey seals, a possibility that is discussed further in section 6.3.

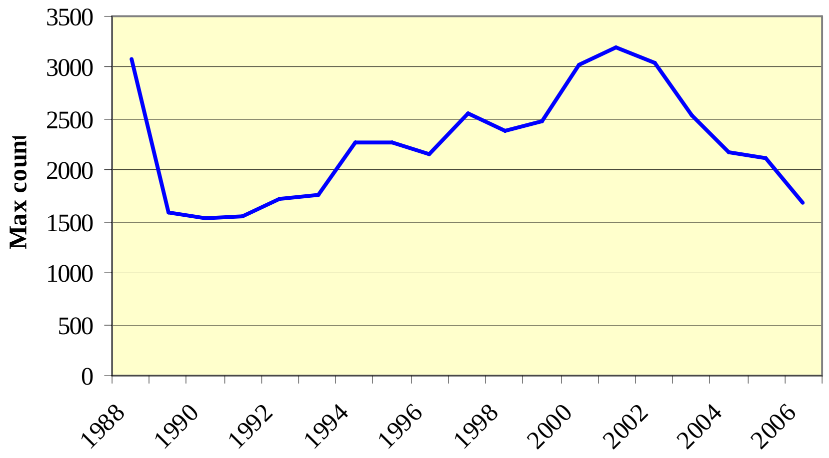


Figure 6. Maximum Harbour seal counts from the Wash from Sea Mammal Research Unit (SMRU) aerial surveys (SCOS & SMRU 2006).

Clearly, such a background level of decline lends weight to the theory that rapid recovery of displaced seals is unlikely. That other sites show a similar extent of decline as the 43% in mean haul out counts from 2002 to 2004 observed at Scroby, suggests that the depth of the decline at Scroby could have even occurred at some time regardless of the wind farm development. Whilst the sudden stepped nature of the response at Scroby can only be explained by construction-related displacement with PDV leading to mortality in 2002/2003 a year before the 2004 decline at Scroby, both the disease and other factors contributing to a wider general decline in Harbour seal numbers may easily have contributed to the depth and extent of the decline observed.

6.3 Cause of change in Grey seal numbers

In direct contrast with Harbour seals, the numbers of Grey seals hauled out on Scroby Sands has continued to increase since 2004, with a notable step increase from a mean (±SE) count of 18 ± 5.8 in 2003 to 52 ± 10.4 in 2004. There is thus no evidence of a direct negative effect of either the construction or operation of the wind farm on haul-out counts of this species. The relative role of the different breeding cycle of Greys, possible interaction with Harbour seals and the underlying population increase in both Norfolk and nationally in explaining the observed patterns is explored below.

Although no monitoring was undertaken during construction, it seems highly likely that relatively few Grey seals were affected by pile-driving. This is simply because all healthy seals of breeding age are likely to be in attendance at breeding colonies from November through to January, coinciding almost exactly with the period of pile-driving (Figure 7). An extended survey programme into the winter period in 2004/05 and 2005/06 in operational years indicates what is thought to be a typical pattern, with less than 15 seals present on Scroby Sands. Aerial survey analysis suggests these are mostly geriatric bull seals.

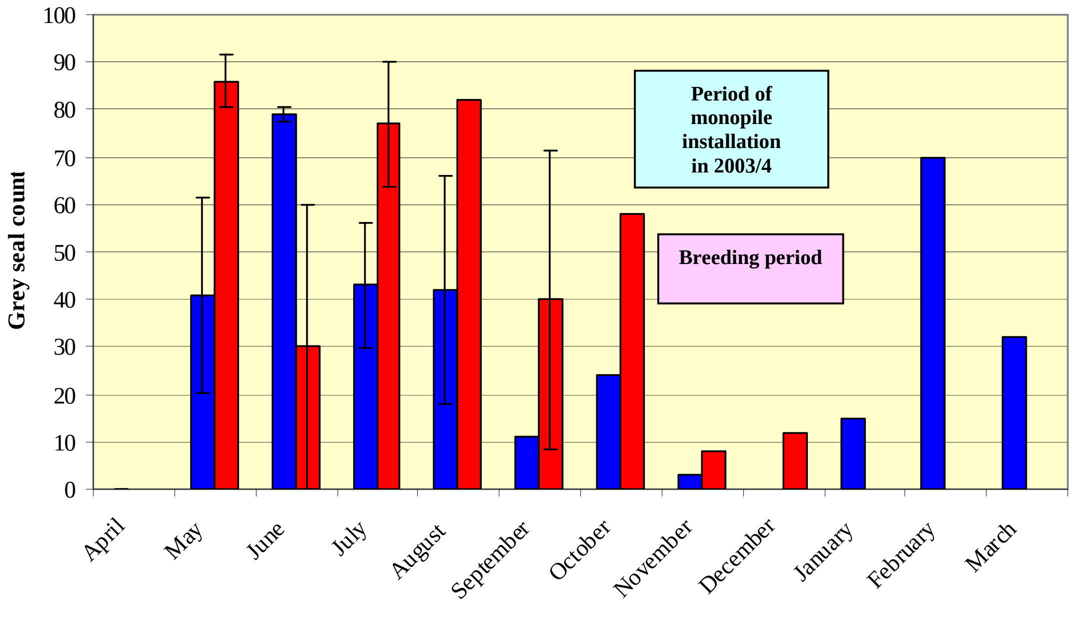


Figure 7. Mean (+1 SE) Grey seal counts made during 2004/5 (blue) and 2005/6 (red) showing the relationship between the use of Scroby, the breeding period and the timing of monopile installation (carried out 21 October 2003 – 1 January 2004).

Although Grey seals used to breed or attempt to breed on Scroby Sands when the sandbank was permanently exposed in the 1960's after Grey seals had colonised Norfolk (Appendix III), this ceased with the disappearance of the bank at high water from 1966 onwards. Breeding began on the beach between Horsey Gap towards Winterton some 20 km from Scroby Sands from 1993, and also at Blakeney Point in North Norfolk (~ 80 km distant). The continued increase in the number of births at Horsey including during the year of construction of 2003/04 (Figure 8) indicates that the potential for negative response of seals to pile-driving at up to 20 km suggested by Thomsen *et al*. (2006) was not obviously realised as a reduction in the attendance of females and number of pups born. There were also no reports of an unusual number of premature births or stillborn pups (J. Hesseltine NE volunteer seal warden, *pers comm*.) and at this distance it appears that breeding was not disturbed.

The close relationship between the number of seals hauled out at Scroby and the births at the Horsey colony, which is invariably closely correlated with the number of cows present, indicates that at a good proportion (but not all typically at the same time) of the same individual seals are likely to be involved (Figure 8). The large foraging range of Grey seals (McConnell *et al*. 1999), suggests, however, possible interchange with a wide number of other colonies such as Donna Nook in Lincolnshire as well as the Farne Islands in Northumberland and even Scottish colonies.

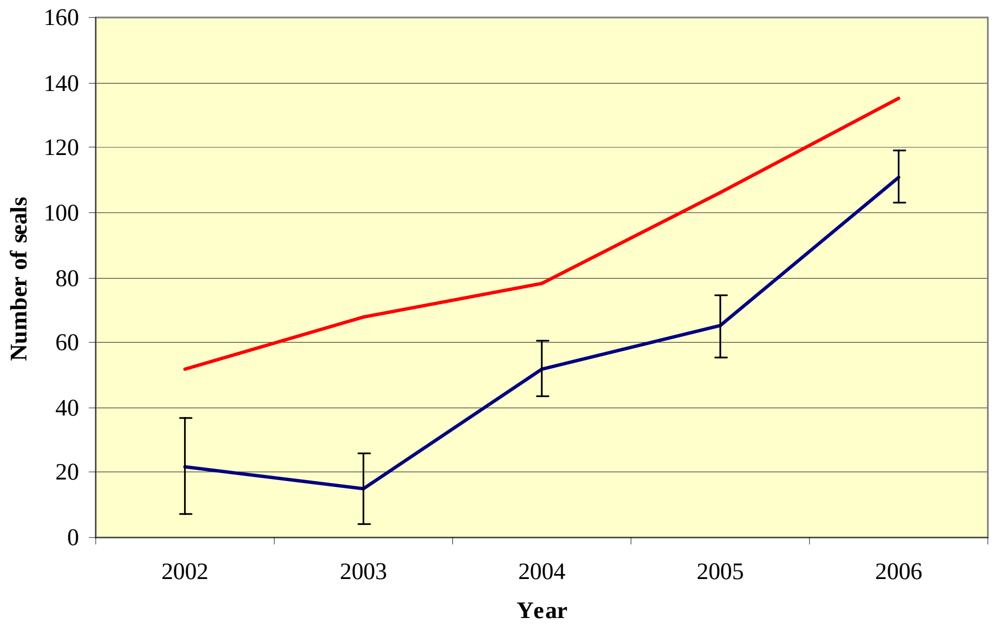


Figure 8. Increase in Grey seal pup numbers born at the Horsey-Winterton colony (red line) compared to mean (±1SE) counts of Grey seals hauled out at Scroby (blue line) over the period 2002-2006. Data for Horsey-Winterton are provided courtesy of J. Heseltine.

Indeed, bearing in mind there were few Grey seals born at the Horsey colony until 2002, coupled with the fact that it takes female Grey seals some 3-5 years to become sexually mature (http://www.pinnipeds.org/species/grey.htm), it seems highly unlikely that local recruitment was responsible for the rapid increase in seals in the area and at Scroby from 2004 onwards. Given rapidity and scale of the increase within such a short time-scale a relatively large-scale influx of Grey seals into Norfolk over the winter of 2003/4 offers the best explanation. The appearance of new breeding colony of Grey seals at Blakeney Point (North Norfolk) in 2004 supports this interpretation (SCOS SMRU 2004). In the summer of 2004 that, for the first time, a small group of seals was regularly observed hauling out on the mainland beaches. This was a mixed group of Grey seals, a number of which were identifiably young-of-the-year, and Harbour seals, reputedly individuals released by the Winterton Seal Sanctuary (J. Heseltine *pers. comm.*). In 2004 the mean count was 34, and ratio of Harbours to Greys was 1.05 (based on observations from 4 independent visits, *pers. obs.*). However, over the past two years, the number of Harbour seals has reduced to about 8 at most (*pers. obs.* from 13 visits carried out from October-December 2006), whilst the Greys, following a highly successful breeding season in 2006, appear to be staying in the area in number. Counts from early March numbered 352 Greys (J. Heseltine *pers. comm.*). Whether some Grey seals continued to use Scroby at the same time remains unknown, although the continued presence of Greys on Scroby during the winter of 2004/2005 suggests that this is a distinct possibility. Therefore, it seems likely that east Norfolk contains several evolving sub-groups of Grey seals.

Unlike the initial colonisation event of Norfolk in the late 1950's (Appendix III), which appears to be have been from the Farne Islands, the most likely origin of the seals in 2003/04 is most likely to have been from the highly successful Grey seal colony at Donna Nook (Lincolnshire). Grey seals at Donna Nook have increased dramatically since its formation in the 1970s, with the virtually exponential increase from around 2002 onwards with a around a 30% increase from ~800 to ~1100 pups in 2004 perhaps the result of previous sustained local recruitment at the colony (Figure 9). Seals from this flat sandy beach colony, as opposed to the rocky coasts and islands used elsewhere in the British Isles, are pre-adapted to the beaches of Norfolk.

A pattern of sharp increase around 2004 only appears to be a feature of Lincolnshire and Norfolk and colonies as numbers in the Farne Islands, the other main colony on the east coast, have been relatively stable over the last five years (Figure 9), whilst on a national scale the rate of increase is levelling off after sustained increase during the 1960's to 1980's particularly (Figure 10). Incidentally, the beginning of this period of increase neatly coincides with the colonisation of Scroby Sands (and Norfolk) by Grey seals.

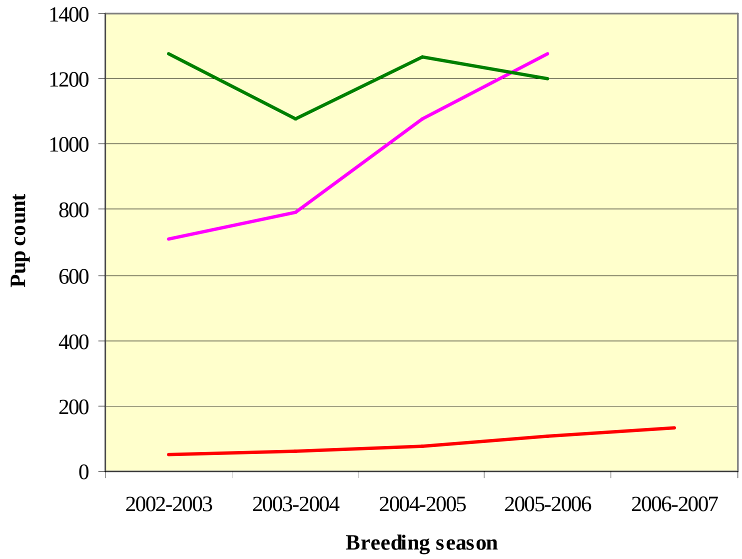


Figure 9. Comparative numbers and trends of Grey seal pups born on The Farne Islands (green line), Donna Nook (pink line), and Horsey (red line) colonies from 2002-2007. Data sources as follows; Farne Islands - SCOS & SMRU 2006, Donna Nook – Lidstone-Scott 2001, Horsey – supplied courtesy of J. Heseltine.

The national increase in Grey seal in the UK from 1,000-2,000 animals in 1914 (Lambert 2002) to an estimated 97,000-159,000 in 2006 (SCOS SMRU 2006, Figure 10) can be related to the 1914 Grey Seals (Protection) Act, which established a close season. Although difficult to enforce on a practical level, the Act essentially halted centuries of subsistence and commercial exploitation of Grey seals resulting in mass population increase (Lambert 2002). However, 90 years on, the population appears to be approaching stabilization. Whilst there is the possibility that global warming and milder drier autumn/winters may benefit Grey seal pup survival and productivity by reducing weather (and storm) related mortality, it is also likely that resource limitation and other density-dependent factors will ultimately prevent further increase beyond a threshold level, which the population appears to be approaching (Figure 10).

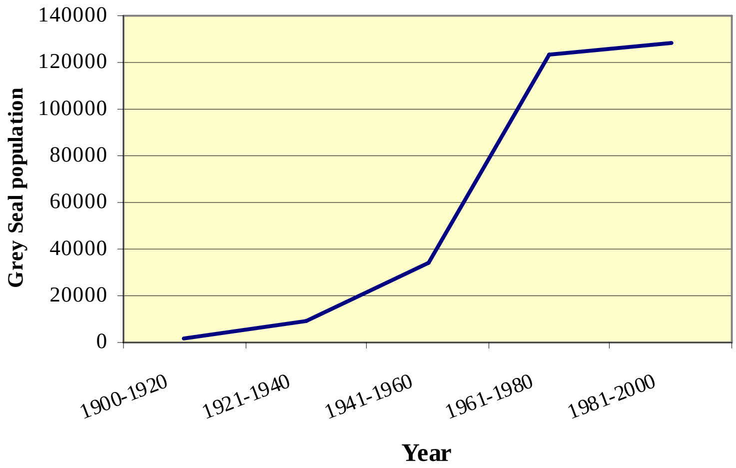


Figure 10. Prospective Grey seal population trends in the UK over the twentieth century. Data from Lambert 2002 (all values to 1960) and SCOS & SMRU (2006) with the value for 2005 being a mean of an estimated population size of 97-159,000 ind.

Clearly, exploitable resources were available both in Lincolnshire and Norfolk for Grey seals to colonise and thereafter increase rapidly. For this to occur, a recent historical increase in the resource base available to Grey seals is implied either through natural increase in a particular (or several) exploitable prey species or habitat, or the presence of an empty niche which could be filled by Grey seals. As there is no evidence of an increase in a particular habitat such as breeding beaches, as these appear to have remained unchanged long before the increase in Grey seals, habitat change is unlikely to be important. Whilst there is some evidence for an increase in species such as Herring *Clupea harengus* as a result of the commercial ban (from 1977 to 1983), which is a species which may be readily exploited by Grey seals, this has also occurred at the same time as a decline in other species such as Cod *Gadus morhua*, which may also be exploited by Grey seals. The biomass available may thus have broadly remained unchanged and again is unlikely to explain a rapid increase.

However, the empty niche theory seems plausible as a result of the rapid decline of the Harbour seal, the characteristic species of shallow, sandy and mixed-bed estuarine waters, which by implication is best adapted to such habitats. Research into the diet and foraging behaviour of Grey and Harbour seals from the Inner Moray Firth (Thompson *et al.* 1996) showed that the two species took similar prey, with sandeels, gadoids, flatfish and cephalopods forming over 95% of the diet in both species. This implies that where resources are scarce in certain sites and in certain years, inter-specific competition is likely occur, although there was no evidence for this in the Moray Firth with the two species utilising different areas. However, this may equally indicate competitive exclusion where the two species co-exist.

It thus remains possible that the decline in Harbour seals in the Wash and wider Norfolk waters as a result of PDV and other as yet unknown factors (see 6.2 above), released any colonising Grey seals from competitive exclusion. That Harbour seals could be competitively superior is opposite to a more general view that Grey seals are superior as a result of larger size promoting greater dive depth and the ability to forage much further afield. Indeed recent research into the foraging behaviour of these species shows that Harbour seals typically make foraging trips of up to 45 km and dive to depths of between 10-50m (Thompson 1990, Tollit *et al.* 1997), whilst Grey seals may undertake extended foraging trips of up to 2100 km and typically forage at greater depths (50-100m) (McConnell *et al.* 1999, Thompson & Fedak 1993). This capacity to travel further and dive deeper enables Grey seals to exploit patchily distributed pelagic prey such as shoaling Herring by exploiting one area and then moving on. Indeed, they may use several haul out sites on an extended foraging trip before they return back to their 'main' haul out site (McConnell *et al.* 1999). By contrast, Harbour seals are more dependent on local resources and potentially therefore more vulnerable to fluctuations in prey. However, their small size means they are able to switch to abundant benthic prey of lower nutritional value (and digestibility) such as shrimps and crabs in periods of low fish abundance. Greys appear to be unable to exploit such prey and are thus forced to travel further afield. In periods of high fish abundance such as the inshore movement of shoaling clupeids perhaps to spawn (ECON 2008), there may enough for all. Thus, the advantage to Grey seals of the absence of Harbour seals may come in periods of moderate fish abundance when Grey seals may be able to exploit local resources, which would otherwise be taken by Harbour seals.

The decline of what appeared to the resident Harbour seals at Scroby Sands as a result of wind farm construction may thus have promoted the rapid increase in Grey seals in this year through the release of competitive exclusion. It remains possible that now, the large number of Grey seals through competition for food and space (accounting for the different haul-out patterns and see Wood 2006) may contribute to the suppression of the recovery of the Harbour seal population. With continued local recruitment into the Grey seal population, if anything, haul-out counts of Grey seals on Scroby Sands seem set to increase further in the coming years, as is occurring at Blakeney Point (Wood 2006). Here, Grey seals now dominate the haul-out, which is a visitor attraction throughout the year (but especially in the summer months) and a successful breeding colony has become firmly established (with 175 pups born in 2005). In contrast, very few Harbour seals now pup on the Point in the summer months.

7. CONCLUSIONS & RECOMMENDATIONS

7.1 Impact assessment of changes in seal numbers at Scroby Sands

Statistically significant changes in the numbers of both seal species were observed during the monitoring programme of Scroby Sands, with strong circumstantial evidence that the decline in numbers of Harbour seals hauled out and breeding colony productivity was linked to the construction of the wind farm. In the case of the statistically significant increase in Grey seals, there was also strong evidence of an underlying increase in Grey seals through coincidental immigration into the area with an additional, but undefined contribution from local recruitment, although there was also potential for an indirect link to the wind farm through competitive release as a result of the decline in Harbour seals.

Environmental Impact Assessment (EIA) relies on the definition of the *sensitivity* of the receptor combined with the *magnitude* of the impact (Table 10) to produce an overall *significance* of any impact within matrix analysis (Table 11). The significance of this impact is then interpreted in a standard manner (Table 12). The process adopted is based on the Environmental Assessment Regulations (HMSO 1999) and on the Institute of Environmental Assessment Guidelines (1995). The definitions of sensitivity and magnitude (see below) follow those developed by Scottish National Heritage (SNH) and the British Wind Energy Association (BWEA) for ornithological assessment (Percival *et al*. 1999) that have become the industry standard in recent offshore wind developments in the Thames (e.g. London Array Ltd 2005) as well as proposed sites in the Wash including Sheringham Shoal (SCIRA Offshore Energy 2006), Lincs (Centrica Energy 2007).

Both Harbour and Grey seal are protected under the Conservation of Seals Act (1970) and internationally under Annex II of the EC Habitats Directive (1992/43/EEC). As a result both are classed as being of *medium* sensitivity.

Table 10. Definition of terms relating to the magnitude of an effect upon a sensitive receptor (species) at a development site.

Magnitude	Definition
Very High	Total loss or very major alteration to key elements/ features of the baseline conditions such that post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether Guide: >80 per cent of population/habitat lost
High	Major alteration to key elements/ features of the baseline (pre-development) conditions such that post development character/composition/attributes will be fundamentally changed Guide: 20 - 80 per cent of population/habitat lost
Medium	Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/ composition/ attributes of baseline will be partially changed Guide: 5 - 20 per cent of population/habitat lost
Low	Minor shift away from baseline conditions Change arising from the loss/ alteration will be discernible but underlying character/ composition/ attributes of baseline condition will be similar to pre-development circumstances/patterns Guide: 1 - 5 per cent of population/habitat lost
Negligible	Very slight change from baseline condition Change barely distinguishable, approximating to the ‘no change’ situation Guide: <1 per cent of population/habitat lost

Table 11. The level of significance of an impact resulting from each combination of receptor sensitivity and the magnitude of the effect upon the receptor.

Magnitude	Sensitivity			
	Very High	High	Medium	Low
Very High	Major	Major	Major	Moderate
High	Major	Major	Moderate	Minor
Medium	Major	Moderate	Minor	Minor
Low	Moderate	Minor	Minor	Negligible
Negligible	Minor	Negligible	Negligible	Negligible

Table 12. Interpretation of significance categories.

Category	Definition of the impact
Major	Gives rise to serious concern and should be considered unacceptable
Moderate	Gives rise to some concern but may be tolerable (depending on its scale and duration)
Minor	Undesirable but of limited concern
Negligible	Not of concern

Working through matrix analysis, the combination of *medium* sensitivity with a *high* magnitude of impact (>20% of population affected) results in a *moderate* significance of construction impact on haul-out counts for Harbour seal (Table 14). Similar impacts had previously been recorded at other wind farm sites (Table 14). Moreover, a *moderate* significance of the impact of construction was also recorded for breeding success, based on pup counts (Table 13). Moderate impacts, although undesirable and giving rise to concern, may be tolerable based on their scale and duration (Table 12).

Whilst a construction impact should intuitively be of short duration, restricted to the period of works activity, this has not proved to be the case for Harbour seal at Scroby Sands as both haul-out counts and breeding success have continued to be depressed into the longer term and the moderate impact has been maintained into the operational period (see results for 2006 in Table 13). Determining whether there is a distinct lower level of impact of operation separate from construction is not possible. However, the negative response of Harbour seals to increased boat traffic, which may continue during maintenance operations and the proven (at other sites) low level of disturbance due to operational noise (Table 14), suggests some continued separate impact of operation, although this is also confounded by natural background population decline and the undetermined possible competitive interaction with Grey seals. No operational impacts have been recorded at other sites, although the potential for a positive indirect effect of turbine bases conferring a reef effect with benefit to fish populations and thus the prey base for seals has been offered (Table 14).

As Grey seals increased over the monitoring period – probably mainly as a result of independent factors such as coincidental immigration to the area perhaps supplemented by some local recruitment in previous years coupled with the possible (but undetermined) indirect effect of competitive release from Harbour seals, in turn displaced from the wind farm – the impact of both construction and operation is *negligible*. The fact that construction was undertaken in the breeding period when Grey seals were naturally absent from Scroby, considerably reduced the number of seals that could be affected. Moreover, as breeding at the breeding site some 20 km away was successful with no unusual levels of infant mortality etc., there was no evidence of an impact of construction noise. This had been a possibility according to the literature (Thomsen *et al*. 2006).

Table 13. Breakdown of the impact assessment upon the Harbour seal haul-out, their breeding success (pups) and the Grey seals haul-out during both construction and operational phases of the Scroby Sands wind farm.

	Harbour seal	Harbour seal pups	Grey seal
Sensitivity of species	Medium	Medium	Medium
Mean baseline count (2002 & 2003)	93	22	18
Mean construction count (2004)	52	52	8
Mean operation count (2006)	63	61	14
Decrease during construction	44%	63%	None*
Magnitude of impact	High	High	Negligible
Significance of impact	Moderate	Moderate	Negligible
Decrease during operation	27%	37%	None*
Magnitude of impact	High	High	Negligible
Significance of impact	Moderate	Moderate	Negligible

* Grey seals continued to increase from the baseline during both construction and operational phases.

Table 14. Evaluation of the impacts of wind farm construction and operation on Harbour and Grey seals

Project Phase: CONSTRUCTION	**Impact description**	**Evidence**	**Likelihood of occurrence**	**Severity**	**Assessment Harbour seals**	**Assessment Grey seals**	**Explanation**
Monopile installation	Disturbance due to noise and vibration	Anecdotal evidence at Scroby: all seals left the area. Evidence from other sites Bockstigen & Nysted - reduced haul out counts during pile driving (Dong Energy 2006, Sundberg & Söderman 2000). Species audigrams & noise records from sites indicates reponse likely up to 20 km away (Thomsen *et al.* 2006)	High	Uncertain for Harbour seal, low for Grey seals.	Moderate	Negligible	Temporary displacement of both species. Impact greater on Harbour seals: 2004 counts after monopile installation were low perhaps indicating a long-term avoidance of the area, also Harbour seals have smaller home ranges and displacement from preferred foraging areas would therefore be of greater consequence.
Tower/nacelle Installation	Disturbance due to increased boat traffic and human activity	Negative (yet statistically insignificant) correlation between boats and haul out counts for Harbour seal only.	Uncertain	Uncertain	Moderate	Negligible	Although not statistically significant, the potential negative correlation between boats and Harbour seals should not be dismissed. Detection of any trend is surprising given the nature of the data (see 6.2).
Scour protection	Disturbance due to boat traffic and human activity	As above	As above	As above	Moderate	Negligible	See above
Project Phase: OPERATION	Disturbance due to underwater noise/vibration	Experimental study (Koschinski *et al.* 2003) shows Harbour seals detected and avoided simulated wind turbine noise by increasing their distance from the source. Audiograms and noise data from existing sites shows detection up to 1 km possible (Thomsen *et al.* 2006).	Proven	Uncertain whether noise simply detectable or whether sufficiently disturbing to affect behaviour.	Low	Low	There is no evidence from other sites such as Horns Reef, Nysted and Bockstigen that Harbour seals are affected by wind farm operation, even if the turbines could be audible over some distance. Given that the haul out site is >1.5km from the turbines it could only affect their use of the array itself and the 1km area around it.
	Increased habitat value (artificial reef effect)	Review of environmental monitoring from Horn's Rev & Nysted (Dong Energy 2006) showed that wind farm construction improved habitat heterogeneity and species diversity.	Very likely	N/A	Beneficial	Beneficial	Potentially beneficial in the long-term if general biological productivity of the area improves.

7.2 Lessons learnt & future considerations

The monitoring programme at Scroby Sands has added considerably to the knowledge base of the impact of wind farm construction and indeed any development near seal-out and breeding sites. This is particularly pertinent to the development of Round 2 sites in the Greater Wash, which contain by far the largest population of Harbour seals in England and are increasingly being used by Grey seals.

The fact that Harbour seal haul-out counts and breeding productivity continued to be depressed until 2006, two years after construction implies that regular monitoring should be continued into the future, as this would prove invaluable in determining the longer-term impact of the operational wind farm at Scroby and of offshore wind farms in general. In relation to Scroby Sands, the large-scale development of the Outer Harbour within a few kilometres (5 km) (within the range occupied by Scroby Sands wind farm), which currently has no obligation to monitor seal populations, has the potential to produce conflicting impacts, and monitoring at least provides the possibility of teasing out the relative impact of the wind farm against the outer harbour and longer term trends in seal populations.

Monitoring need not be annual (partly given the gap in data since 2006), but could be conducted at 2-5 year intervals, with three years perhaps the most pragmatic solution. Should monitoring be conducted at such an interval, the same intensity of monitoring as conducted in the monitoring programme to date (i.e. ~12 surveys with a focus on the Harbour seal pupping period) is recommended. An alternative suggestion is to partition the same sampling effort within a reduced monitoring programme of say, four surveys per annum, but conducted annually or biannually. Additional data (i.e. wind speed, direction, tidal state etc) that may influence haul-out counts should also be gathered as a matter of course.

As well as further works at Scroby Sands it is recommended that further consideration is giving to a number of issues surrounding the site selection, construction, operation and monitoring of offshore wind farm particularly with the recent announcement of Round 3 (www.thecrownestate.co.uk/offshore_wind_energy and follow latest news headlines). This is undertaken below.

7.2.1 Site selection

In view of the data presented in Thomsen *et al.* 2006, it is recommended that wind farms are not built within 1km of haul out sites, as operational noise is likely to be detectable by seals at this distance. It is not known whether seals continue to use the wind farm area once the development is installed. Therefore, it is hard to quantify potential habitat loss/displacement that might be caused by wind farm development. Until more information is available, caution is required building numerous sites, or sites of significant size near Harbour seal colonies. One method might be to take the foraging range as being that within a 40km area of the site and proportion the amount of sea taken up by developments, and then use matrix analysis to determine potential significance of impacts. If looking at the suitability of wider areas, satellite telemetry could be employed to investigate potential foraging areas and routes in order to inform site selection.

7.2.2 Pile Driving

Observational data from Bockstigen and aerial survey and remote video monitoring from Nysted indicate that pile driving has a significant negative effect on the number of seals (of both species) hauling out. This is supported by anecdotal evidence from Scroby, which was not monitored at this time, although local fishermen reported the appearance of large numbers of seals to the south at Southwold, Suffolk. Recent studies of Harbour seal hearing and pile driving suggest that Harbour seals are likely to hear the noise up to 80 km away, and are likely to respond up to 20 km away (Thomsen *et al.* 2006). Recommendations to minimise the disturbance impacts of pile driving are as follows:

- Consideration of other potentially less noisy alternative methods of installation in sites near seal colonies (i.e. within 20 km).
- If pile driving is undertaken, it should not be carried out when seals are pupping. Grey seals pup in winter and Harbour in summer, with peak pupping period varying between sites.
- When sites are close together it is recommended that pile driving does not occur on more than one site at a time.
- Seal scrammers should be used to deter seals from the area before pile driving starts in order to avoid inflicting hearing damage.
- Monitor haul out counts before, during and after pile driving at wind farms <20km from seal haul out sites. Post-construction monitoring is a critical element of this process, since recovery of counts after disturbance needs to be confirmed.

7.2.3 Vessel traffic

Seals can respond to increased vessel traffic, especially if located in isolated areas and unused to human activities. To minimize disturbance it is recommended that vessel routes to and from sites do not pass close to seal haul out sites unless an alternative is not available. Observational monitoring of responses of seals to boats could be used to ensure that boat routes used are not disturbing seals.

7.2.4 Operational noise

Whilst no operational impacts of wind farms have been detected, it is likely Harbour seals will detect operational noise at distances of up to 1 km (Thomsen *et al.* 2006) although it is not known what effect this low-level noise would have on seal behaviour at sea (social interactions etc.). Thus a wind farm could potentially reduce the favourability of the habitat for seals. If this takes the form of avoidance, it is possible that future larger sites could result in significant habitat displacement. Further work is required to ascertain whether seals use or avoid existing offshore wind farm sites. Although problematic, satellite telemetry is probably the best technique available for doing this.

7.2.5 Monitoring

Future monitoring programmes must either address the causes of any changes detected, or monitor potential impacts in order to actively investigate the mechanisms by which seals might be affected by the development.

Haul out counts can be heavily influenced by a number of factors, such as wind speed, wind direction, season, time of day and tidal state, which differ between sites. It is recommended that either the factors affecting counts specifically investigated before the start of the aerial survey programme, or potentially influential environmental variables are monitored as a matter of course (which approach is more suitable depends on existing knowledge of the site). Gathering this additional data enables counts to be corrected for other influential factors and increases data quality.

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Appendix I

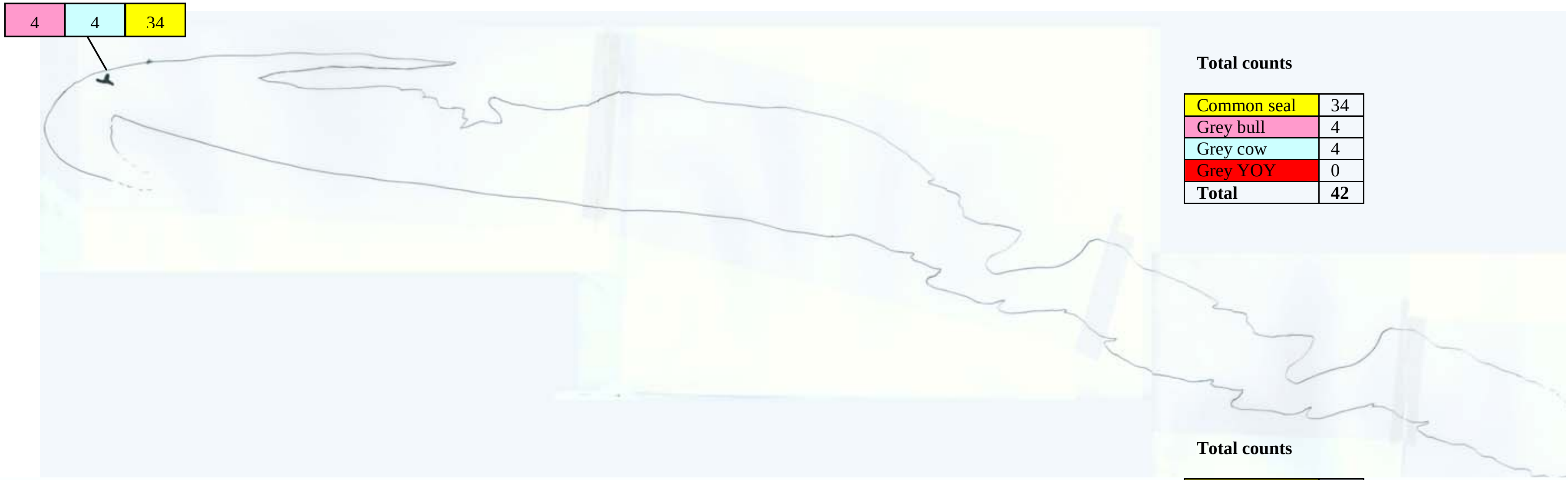
A break down of seal counts from each of the 11 surveys carried out in winter 2005/summer 2006

Table 4. Counts of the various groups and total counts of Common and Grey seals from the winter 2005 (W) and summer 2006 (S) aerial surveys. Winter surveys are shown in italics, whilst breeding surveys are shaded.

		Common Seal			Grey Seals				
Survey no.	**Date**	**Adult**	**Pup**	**Total**	**Bull**	**Cow**	**YOY**	**Total**	**Grand Total**
W1	*17-Nov*	*34*	*0*	*34*	*4*	*4*	*0*	*8*	*42*
W2	*10-Dec*	*13*	*0*	*13*	*9*	*3*	*0*	*12*	*25*
S1	16-May	94	0	94	43	47	3	93	187
S2	08-Jun	42	0	42	19	25	1	45	87
S3	22-Jun	70	11	81	56	54	1	111	192
S4	30-Jun	17	5	22	1	10	0	11	33
S5	03-Jul	50	5	55	21	33	0	52	109
S6	07-Jul	40	16	56	30	28	0	58	114
S7	10-Jul	35	28	63	11	23	9	43	106
S8	25-Jul	37	16	53	10	9	0	19	72
S9	05-Aug	87	27	114	67	74	0	141	255
S10	29-Aug	67	15x	82	9	27	0	36	118
S11	21-Oct	90	0	90	17	43	0	60	150

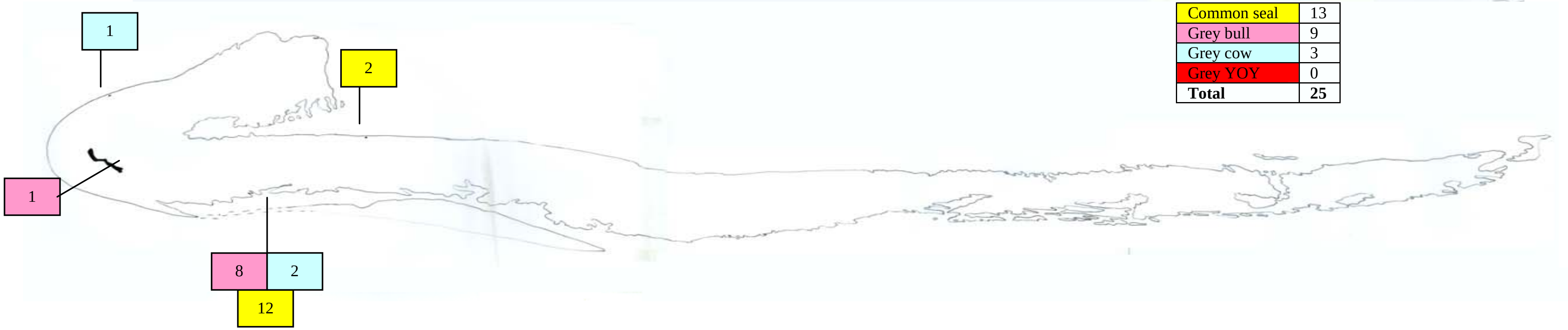
Appendix II

Maps of seals hauled out on Scroby Sands during surveys from winter 2005/6 and summer 2006.



Total counts

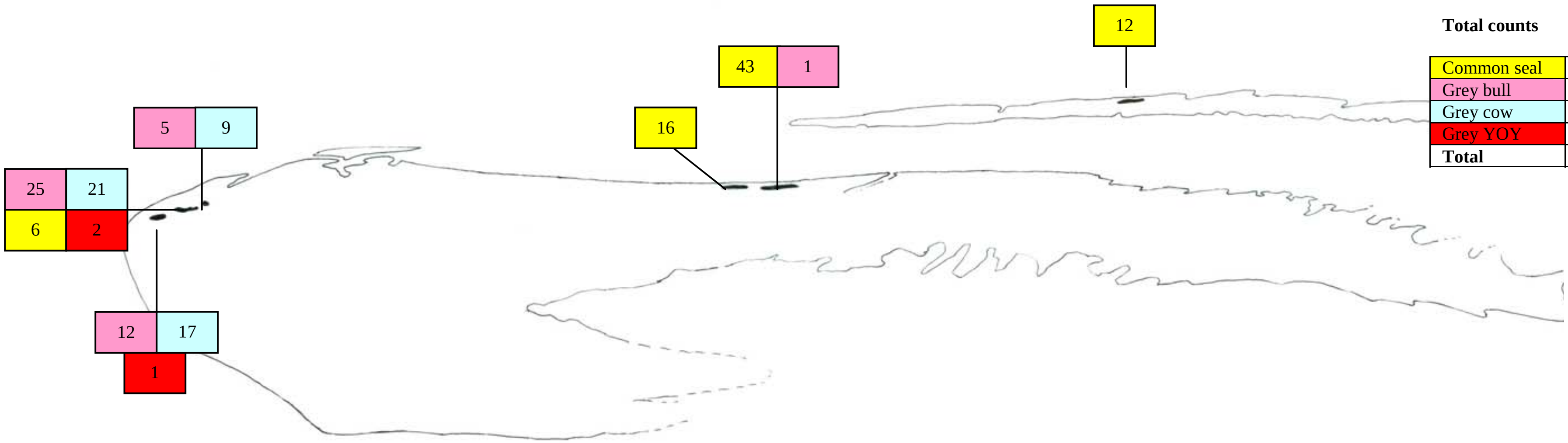
Common seal	34
Grey bull	4
Grey cow	4
Grey YOY	0
Total	**42**



Total counts

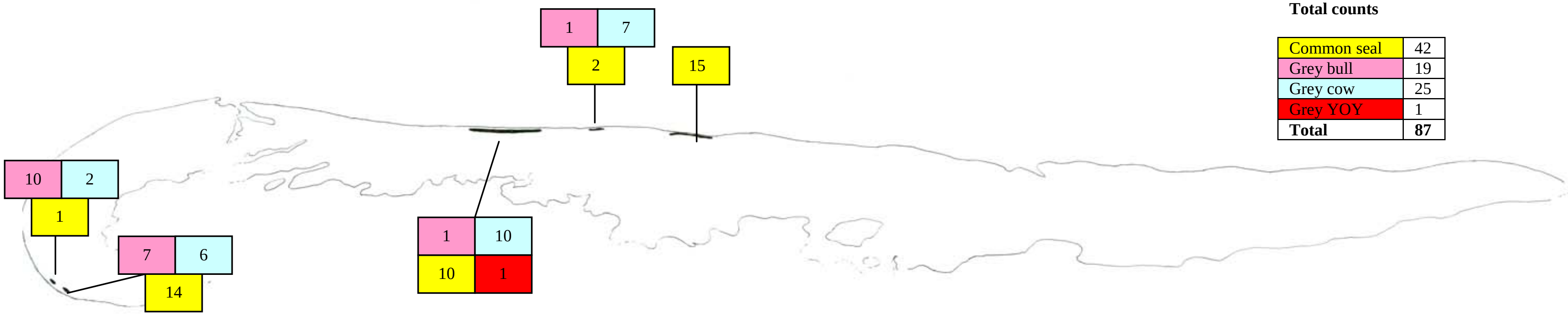
Common seal	13
Grey bull	9
Grey cow	3
Grey YOY	0
Total	**25**

Figure 4 &5. Abundance and distribution of seals hauled out in Winter surveys carries out 17th November (top) and 10th December (bottom) 2005.



Total counts

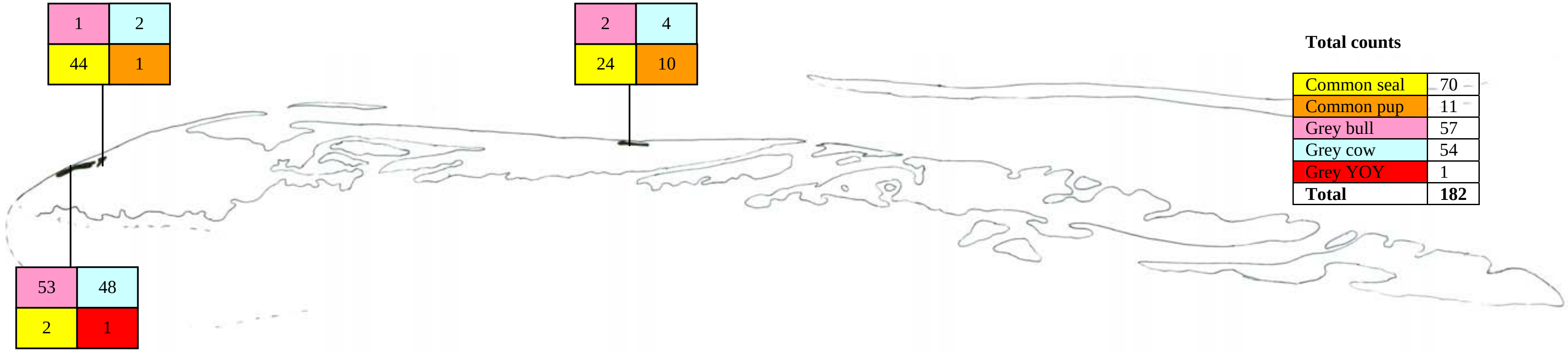
Common seal	77
Grey bull	43
Grey cow	47
Grey YOY	3
Total	**25**



Total counts

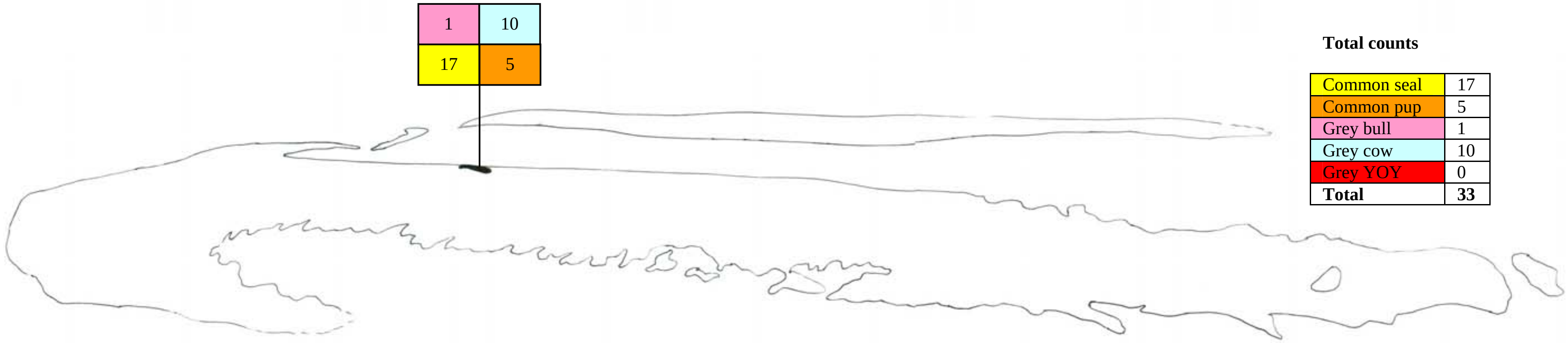
Common seal	42
Grey bull	19
Grey cow	25
Grey YOY	1
Total	**87**

Figures 6 & 7. Abundance and distribution of seals hauled out on 16th May (above) and 8th June (below) 2006.



Total counts

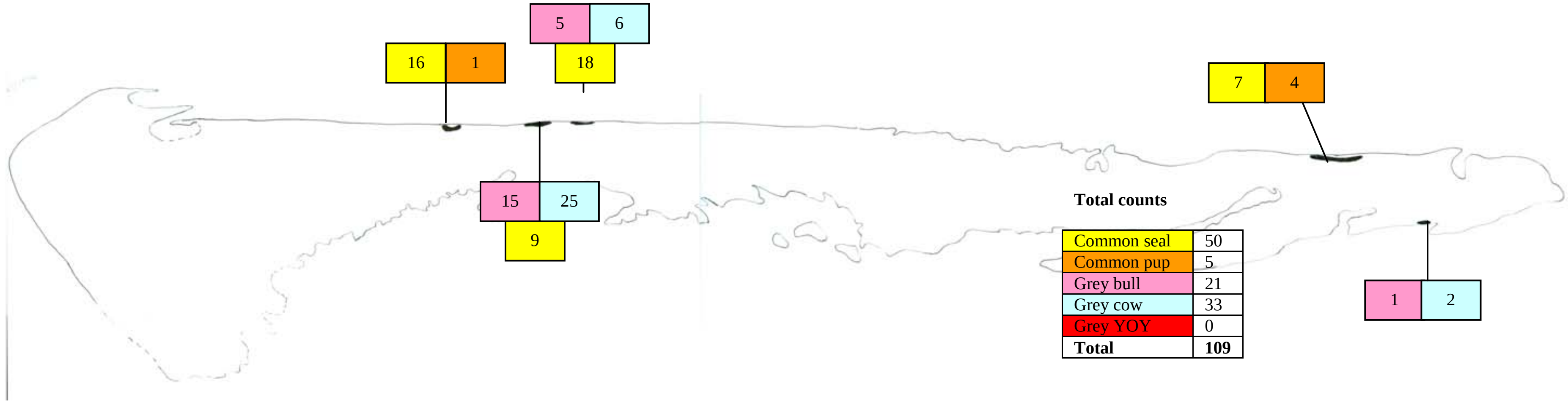
Common seal	70
Common pup	11
Grey bull	57
Grey cow	54
Grey YOY	1
Total	**182**



Total counts

Common seal	17
Common pup	5
Grey bull	1
Grey cow	10
Grey YOY	0
Total	**33**

Figures 8 and 9. Abundance and distribution of seals hauled out on 22nd (above) and 30th (below) June 2006.



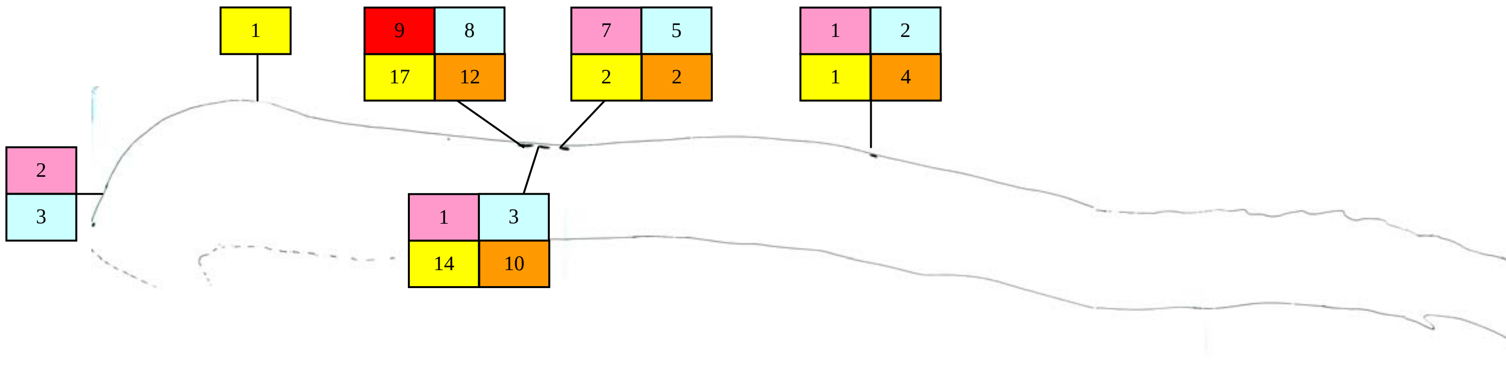
Total counts

Common seal	50
Common pup	5
Grey bull	21
Grey cow	33
Grey YOY	0
Total	**109**

Total counts

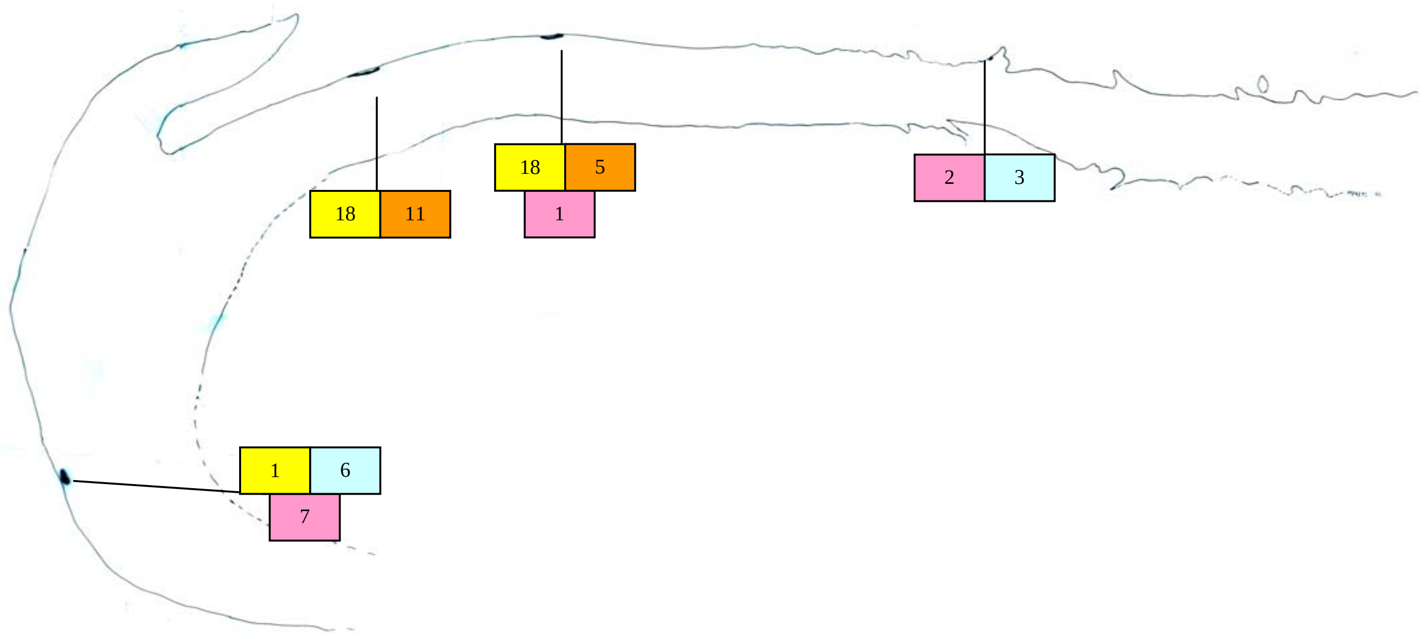
Common seal	40
Common pup	16
Grey bull	30
Grey cow	28
Grey YOY	0
Total	**114**

Figures 10 and 11. Abundance and distribution of seals hauled out on 3rd (above) and 7th (below) July 2006.



Total counts

Common seal	35
Common pup	28
Grey bull	11
Grey cow	21
Grey YOY	9
Total	**106**



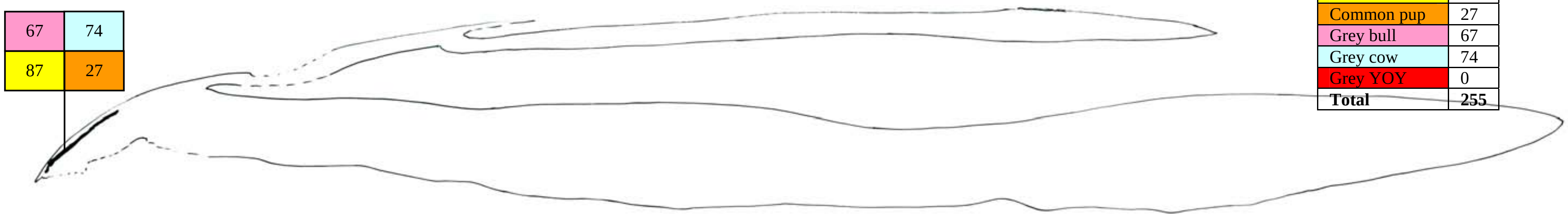
Total counts

Common seal	37
Common pup	16
Grey bull	10
Grey cow	9
Grey YOY	0
Total	**72**

Figures 11 and 12. Abundance and distribution of seals hauled out on 10th (above) and 25th (below) July 2006.

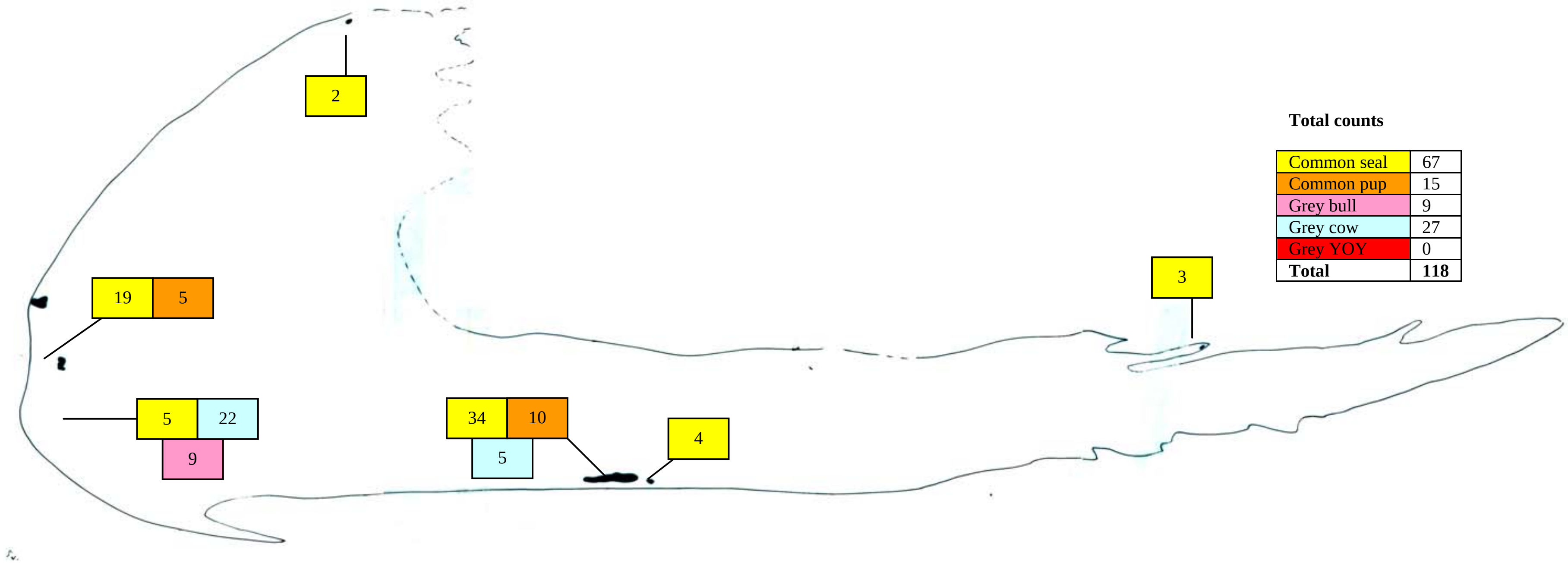
Total counts

Common seal	87
Common pup	27
Grey bull	67
Grey cow	74
Grey YOY	0
Total	**255**

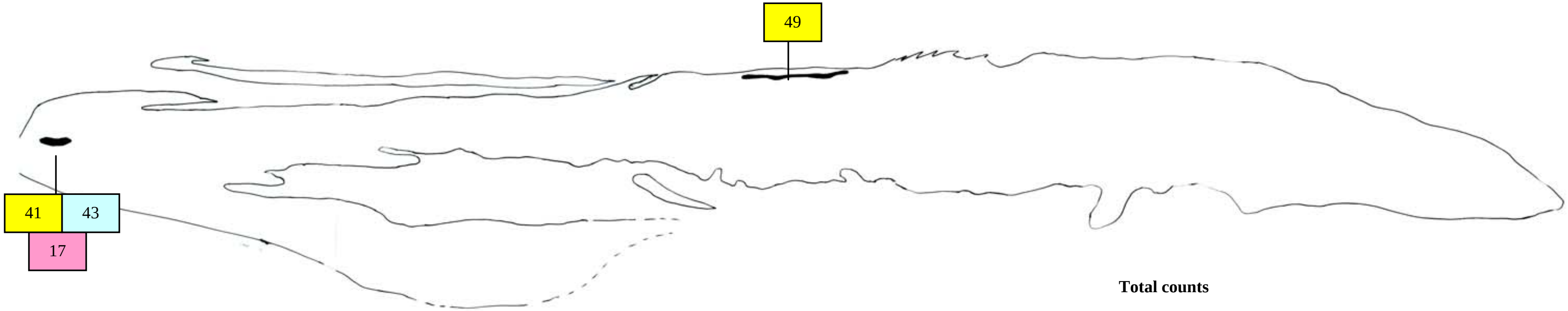


Total counts

Common seal	67
Common pup	15
Grey bull	9
Grey cow	27
Grey YOY	0
Total	**118**



Figures 13 and 14. Abundance and distribution of seals hauled out on 5th (above) and 28th (below) August 2006.



Total counts

Common seal	90
Common pup	0
Grey bull	17
Grey cow	43
Grey YOY	0
Total	**150**

Figures 15. Abundance and distribution of seals hauled out on 21st October 2006.

Appendix III

Seal counts for Scroby 1958-2006

Seal counts for Scroby taken from the Transactions of the Norfolk and Norwich Naturalists Society

Year and date (if known)	Number of seals at Scroby		Comments
	Grey	**Common**	
<u>1958</u> **Oct**	6-7	No records.	The 8 Grey seal pups found on Scroby on 7 Dec were tagged by Prof Hewer from Imperial College. (First official records of Grey seals in Norfolk)
29 Nov	100 (nr sandbank)		
7 Dec	4 pups, 1 bull, several cows in with common herd		
<u>1959</u> **7 June**	No records	Breeding season described as 'very good'	
<u>1960</u> **6 June**		150	The sands changed little during the winter, the highest parts lying at the north-east and south-east corners of the island (3 feet above high water). Visit to monitor little terns on 23 July (after storms had come and covered these banks) describes greater black-backed gulls quarrelling over the carcasses of common seal pups. Report of a tail-tagged animal seen on May 15th, although impossible to approach closely.
16 June		40	
end June		25 pups	
3 July		200 (seeking shelter from gales)	
16 Aug		132	
24 Nov	4 pups seen by RAF.		
16 Dec	12 pups		
<u>1961</u> **2 July**		80 adults, 6 pups (all under 1 wk old)	North-westerly gales and abnormally high tides reported July 4th. Unsettled weather prevented landing until July 14th (i.e. during the Common Seal breeding season.).
14 July	18	2 herds; 150 adults in total with 16 pups (most under 1 wk old, 2 later found dead)	By end July large numbers of black gulls were devouring the carcasses of common seal pups. Stranding of pups/young seals occurred at Horsey, Cley, Yarmouth South Denes, Caister, Winterton, Hopton and West Runton.
21 July	47 (one herd of 27 and another of 20)	3 herds, but total no adults still 150. Only 2 pups ashore, rest at sea.	
19 Nov	3 pups; 2 male, 1 female		
26 Nov	5 pups; 4 male, 1 female		
3 Dec	2 pups; 1 male, 1 female		Later in November 3 Common Seals hauled out on a knoll below Breydon bridge and spent the winter there in spite of considerable human activity on the railway, bridge and barges.
10 Dec	1 female pup		

1962 **18 June**		60 adults; about half on NE corner, the rest offshore	Bad weather from during late June until 8th July (breeding season). Abnormally high tides and strong winds prevented visits prior to Dec 4th. Bad weather after this visit doubtless had a serious effect on the survival of these pups, one was washed ashore at Yarmouth on 12 Dec.
8 July		30 pups (less than a few days old). A few dead/very weak	
28 July	18 resting on NW corner	100 adults, 20 pups	
4 Dec	10 pups		
1963 30 June	Small groups of 10-20 Greys seen during summer.	200 adults (peak no seen during summer)	Bad weather reported June 18th, however seals seem to have bred successfully in spite of this.
14 July		17 pups found (all less than a few days old)	
30 July		6 pups found dead	
27 Dec	7 live pups, 2 dead pups		Some of these were already in moult.
1964 **June**		120-200 seen throughout month	The report mentions that the colony has a high mortality rate (no figures given). This can again be explained by high tides that occurred end June and mid July.
25 June		9 pups	
'Winter' (no date given)	12 pups seen for certain. Population of adults estimated at 300		Some attempts at shooting Common Seals on Scroby (for skins), but only shot 6 animals. They were deterred by naturalists and boatmen who take visitors to see the seals.
1965 **19 July**	27	100	Also reliable sightings of Greys on beaches at Weybourne and Winterton.. One Common Seal ringed at Scroby was found 5 weeks later in a Norwegian fjord, and another was recovered from West Africa. Scroby Island decreases in size by at least 50% between mid-summer 1964 and 1965. The original island had become circular by July 1965 and a sandbank had formed to the north-west with a quarter mile channel between the 2 islands. This new section was about 3.5 miles long at low tide, extending from Yarmouth to California.
1966	Did not breed due to adverse weather and changes in the shape of Scroby	Described as having a 'difficult year'	Throughout the year Scroby was completely submerged long before each high tide.
1967 27 June	15 (though did not breed)	80	Scroby remained below high water level. At low tide a new island a mile long appeared a quarter of a mile to the north.

1968 **Winter**	200 seals present with some 80-100 estimated to be at sea. Ratio of common to Grey 5:3		Scroby cull, authorized by the Ministryof Agriculture and Fisheries, started 16 May with the intention of killing 75 seals. Only 9 were killed in the first week, and subsequently the cull was called off. The Grey seals were tagged by the Seal Research Division (then in Lowestoft) to determine whether the pups could survive now the island is inundated by high tides. During the third week of December only 75 seals were counted on Scroby, and some of the tagged seals were washed up on the beaches between Yarmouth and Caister. This seems to indicate survival chances were slim.
1969	No mention of numbers at Scroby, although there were reports of individuals spotted as several points on the north and east coasts	Numbers described as 'same as last year'	No comments given as to the state of Scroby itself.
1970 No date given		200-250 adults, 20-30 pups.	Scroby reported to be making up again following its disappearance in 1966.
3 Dec	50-70 adults, 18 pups (2 of which were later washed ashore at Yarmouth)		
1971 7 June	10	200+ 20-30 pups born	Further sand continues to build up leaving a small area completely dry on most tides. This improved breeding success. One Grey pupped on the beach at Hopton. There were other reports of single individuals, dead and alive, from many other places along the coastline.
9 Sept	47		
11 Dec	5 pups; 3 new born, one 2 weeks old, and one offshore.		
1972	100+ with 20 pups born Dec/Jan	Described as about the same as 1971	
1973 – 1974	No data available		
1975	Described as producing about 25 pups annually	Numbers described as 'remaining constant'	
1976	No data available		

1977	Some cow pupped, but they were all lost.		Scroby Sand disappeared under water during the Grey Seal breeding season. Several Greys pupped on the mainland beaches, but again all the pups were lost.
1978			Large numbers of Grey seal pups washed ashore on beaches
1979			Grey seal pups washed ashore on beaches again, although not to the same extent as 1978.
1980	Bulls established territories for breeding but as the cows began to arrive the sands washed away.	'Reasonably good season'	Commons from Scroby picked out later at Morston, Blakeney and in the Wash. The Grey bulls displaced from Scroby set up alternative territories on mainland beaches and cows ended up pupping near fishermen, and then deserting their pups. A number were also shot, and severely wounded seals then had to be destroyed. It was reported that some went to Holland instead.
1981	Greys did not stay this year.		The island was very unstable, so they Greys did not stay; some pupped on the mainland beaches but fewer than in 1980.
1982	No data		
1983	Scroby submerged; seals unable to breed	'Average successful year'	5 Grey seal pups found deserted on beach – however seals unable to pup at Winterton because of the construction of the sea wall. It is assumed that they carried on to Morston.
1984	No data		
1985	Bulls set up territories, but sands were covered by the time the cows arrived.	120	Some Grey cows dropped pups at sea; several cows pupped on beach, but all the pups were deserted. Some of these seals were marked and later found at Morston.
1986	Scroby submerged. Several cow dropped pups at low tide, which were then lost when the waters rose. Others came ashore but all the youngsters died or had to be put down.	Common seals hauled out and pupped at Winterton with greater success than the Greys (since their pups were able to take to the sea and avoid people, dogs and other animals). However 6 of the 18 pups died, bitten by dogs.	
1987	28 Greys seen at Horsey on 21 April – reputedly the most seen there for years.		
1988	The Grey seals did not come to Scroby or Horsey this year.	30 (reduced from 120, poss due to PDV outbreak)	
1989-1991	No data		
1992	No references to seals		
1993	15-20. Attempted to give birth on mainland beaches. 2 pups sighted.	60	
1994	200 (on Scroby).	90	One report mentions 6 pups born on beach between Horsey and Winterton, though none survived. Another conflicting report mentions that 4 pups had been born by 1 Dec, of which 3 survived.

1995		120 adults, 15 pups successfully reared.	Tidal surge reduced area of sand from 20 to 5 km^2. Greys bred at the Horsey-Winterton site: 2 pups sighted 25 Noc, and 3 pups fatally shot Boxing Day.
1996 **10 Jan**	Bred at Horsey Winterton: 6 pups (one dead), 2 bulls, 3 cows		
1997	Bred at Horsey-Winterton: 15 pups (1 dead, 1 with bite wound), also 6 bulls and one Common seal.		No mention of number of Grey cows.
1998	Bred at Horsey-Winterton: 17 pups (2 died). 5 bulls seen.		
1999			
2000			
2001			
2002	Bred Horsey-Winterton: 52 live births over breeding period (Nov-Jan). (Data source: J. Heseltine NE volunteer seal warden)	Max count 67 pups (July) (Data source: Scroby monitoring)	Start of voluntary wardening by local seal enthusiast John Heseltine.
2003 c	Bred Horsey-Winterton: 68 live births, although 10-15 pups died in major storm event. (Data source: J. Heseltine NE volunteer seal warden)	Max count 42 pups (August) (Data source: Scroby monitoring)	
2004	Bred Horsey-Winterton 78 live births (5 pups died) (Data source: J. Heseltine NE volunteer seal warden)	Max count 16 pups (July) (Data source: Scroby monitoring)	(28 Nov – people count 14, 26 Dec 107 people and 23 dogs on beach, of the 33 pups present only 17 were with their cows – *pers. obs*))
2005 4 Dec	Bred Horsey-Wint: 106 live births (6 pup deaths). (Data source: J. Heseltine NE volunteer seal warden)	Max count 28 pups (July) (Data source: Scroby monitoring)	Increased public interest in seals – NE respond by producing signs and leaflets advising on public behaviour, although there are issues with signs not being big enough. Visitors stopped on several occasions from directly approaching seals. Colony visited by Miriam Duck of Sparsholt College Hampshire as part of a survey of seal colonies in the east of England, and also by the BBC Archive film unit.
2006	Bred Horsey-Wint: 135 live births in total. (Data source: J. Heseltine NE volunteer seal warden)	Max count 28 pups (July) (Data source: Scroby monitoring)	Increased wardening coupled with a larger but more dispersed colony helped reduce visitor pressure, with one small section of the beach (near Horsey Gap car park) receiving the majority of the visitors (and wardened stringently). In general visitors kept off the beach. The temperatures and beach condition are also thought to have contributed to successful breeding.

Appendix IV

Results of the aerial seal surveys conducted at Scroby in baseline (2002 and 2003), construction (2004) and operational (2005 and 2006) monitoring of the Scroby Sands Offshore Wind Farm

Baseline surveys: 2002 and 2003

YEAR	SURVEY NO	DATE	SEASON	CS ADULT	CS PUP	COMMON (UNKNOWN)	TOTAL CS	GS BULL	GS COW	GS YOY	GREY (UNKNOWN)	TOTAL GREYS	UNID SEALS	TOTAL SEALS	NOTES
2002	1	25-May	SPRING	57	12	0	69				0	0	19	88	
2002	2	11-Jun	EARLY SUMMER	80	16	0	96				0	0	4	100	
2002	3	26-Jun	PUPPING	75	7	0	82				0	0	11	93	
2002	4	04-Jul	PUPPING	66	67	47	180				0	0	10	190	
2002	5	19-Jul	LATE SUMMER	149	18	24	191				0	0	12	203	
2002	6	27-Jul	LATE SUMMER	93	0	12	105				0	0	7	112	
2002	7	21-Aug	LATE SUMMER	58	2	13	73				0	0	4	77	
2002	8	01-Sep	EARLY AUTUMN	70	1	5	76				98	98	7	181	
2002	9	16-Sep	EARLY AUTUMN	74	0	2	76				98	98	11	185	
2002	10	26-Sep	EARLY AUTUMN	69	0	62	131				20	20	40	191	
2003	1	08-Apr	SPRING	87	0	5	92	0	0	0	0	0		92	
2003	2	18-Apr	SPRING	77	0	1	78	0	0	0	0	0		78	
2003	3	04-May	SPRING	56	0	18	74	0	0	0	22	22		96	
2003	4	15-May	SPRING	116	0	1	117	0	0	0	0	0		117	
2003	5	30-May	SPRING	14	0	1	15	13	14	16	8	51		66	
2003	6	12-Jun	EARLY SUMMER	45	0	0	45	9	10	0	13	32		77	
2003	7	30-Jun	PUPPING	40	14	2	56	8	3	0	2	13		69	
2003	8	14-Jul	PUPPING	43	16	0	59	7	23	4	7	41		100	
2003	9	28-Jul	LATE SUMMER	87	23	0	110	2	3	0	7	12		122	
2003	10	19-Aug	LATE SUMMER	113	42	0	155	0	0	0	4	4		159	
2003	11	13-Sep	EARLY AUTUMN	92	13	0	105	0	0	0	0	0		105	
2003	12	06-Oct	EARLY AUTUMN	52	29	0	81	0	0	0	0	0		81	

Construction surveys: 2004

YEAR	SURVEY NO	DATE	SEASON	CS ADULT	CS PUP	COMMON (UNKNOWN)	TOTAL CS	GS BULL	GS COW	GS YOY	GREY (UNKNOWN)	TOTAL GREYS	UNID SEALS	TOTAL SEALS	NOTES
2004	1	19-Apr	SPRING	19	0		19	21	5	15	17	58		77	Start of site photos: 1 boat
2004	2	12-May	SPRING	40	0		40	8	41	8	8	65		105	
2004	3	21-May	SPRING	40	0		40	20	28	10	0	58		98	3 boats
2004	4	31-May	SPRING	33	0		33	0	0	0	0	0		33	3 boats
2004	5	11-Jun	EARLY SUMMER	21	0		21	31	40	5	4	80		101	5 boats
2004	6	30-Jun	PUPPING	27	3		30	44	23	9	1	77		107	BAR: 10CS, 3 CP, 3 boats
2004	7	02-Jul	PUPPING	53	3		56	31	31	0	15	77		133	BAR: 9 CS, 2 CP, 10 GB, 4 GC, 2 boats
2004	8	06-Jul	PUPPING	45	4		49	7	10	0	2	19		68	BAR: 19 CS, 3 CP, 5 GB, 4 GC, 1 G (unknown), 2 boats
2004	9	10-Jul	PUPPING	68	12		80	27	24	6	14	71		151	1 boat
2004	10	15-Jul	LATE SUMMER	41	10		51	9	5	0	1	15		66	BAR: 6 CS, 3 GB, 4 GC, 1 boat
2004	12	17-Aug	LATE SUMMER	40	8		48	6	8	0	4	18		66	
2004	14	10-Sep	EARLY AUTUMN	149	12		161	32	88	1	22	143		304	
2004	15	05-Oct	EARLY AUTUMN	37	12		49	16	18	0	24	58		107	

Operational surveys: 2005-2006

YEAR	SURVEY NO	DATE	SEASON	CS ADULT	CS PUP	COMMON (UNKNOWN)	TOTAL CS	GS BULL	GS COW	GS YOY	GREY (UNKNOWN)	TOTAL GREYS	UNID SEALS	TOTAL SEALS	NOTES
2005	*17*	*08-Jan*	*WINTER*	*23*	*0*		*23*	*2*	*5*	*0*	*8*	*15*		*38*	
2005	*18*	*04-Feb*	*WINTER*	*31*	*0*		*31*	*20*	*50*	*0*	*0*	*70*		*101*	
2005	*19*	*08-Mar*	*WINTER*	*17*	*0*		*17*	*11*	*20*	*1*	*0*	*32*		*49*	
2005	1	05-May	SPRING	16	0		16	29	42	9		80	0	96	
2005	2	28-May	SPRING	35	0		35	28	59	4		91	0	126	
2005	3	10-Jun	EARLY SUMMER	30	10		40	29	23	7		59	0	99	
2005	4	21-Jun	EARLY SUMMER	0	0		0	0	0	0		0	101	101	
2005	5	05-Jul	PUPPING	61	15		76	43	31	1		75	0	151	
2005	6	10-Jul	PUPPING	39	28		67	50	64	8		122	0	189	
2005	7	15-Jul	LATE SUMMER	47	16		63	44	37	5		86	0	149	
2005	8	19-Jul	LATE SUMMER	81	19		100	30	14	4		48	0	148	
2005	9	31-Jul	LATE SUMMER	86	16		102	36	18	1		55	0	157	
2005	10	08-Aug	LATE SUMMER	67	11		78	22	60	0		82	0	160	
2005	11	05-Sep	EARLY AUTUMN	77	17		94	33	38	0		71	0	165	
2005	12	13-Sep	EARLY AUTUMN	18	1		19	1	7	0		8	84	111	
2005	13	26-Oct	LATE AUTUMN	84	0		84	18	40	0		58	0	142	
2005	*14*	*17-Nov*	*WINTER*	*34*	*0*		*34*	*4*	*4*	*0*		*8*	*0*	*42*	
2005	*16*	*10-Dec*	*WINTER*	*13*	*0*		*13*	*9*	*3*	*0*		*12*	*0*	*25*	
2006	1	16-May	SPRING	94	0		94	43	47	3		93	0	187	36 CS PREG