ECON
ECOLOGICAL CONSULTANCY
NORWICH RESEARCH PARK
COLNEY LANE
NORWICH NR4 7UH
TEL. (01603) 450 929
EMAIL: m.perrow@econ-ecology.com

Scroby Sands Seal Monitoring:

Analysis of the 2005 post-construction aerial surveys

November 2005

Draft Final Report

Prepared by:

Eleanor Skeate
Dr Martin R. Perrow

ECON Ecological Consultancy
Norwich Research Park
Colney Lane
Norwich
NR4 7UH

For and on behalf of:
E.ON UK Renewables Offshore Wind Limited

Project manager:

Chris Smith

Asset Leader
E.ON UK Renewables
Room 108
Power Technology Centre
Ratcliffe on Soar
Nottingham
NG11 0EE

EXECUTIVE SUMMARY

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 Great Yarmouth, Norfolk.

The development is located about 2 km north of an area used by Common seals *Phoca vitulina* as a breeding and haul out site and by Grey seals *Haliochoerus grypus* for haul out. The Schedule to Licence required that a monitoring programme be carried out to determine the impact of the wind farm on the seals. 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, and construction data was gathered in 2004. The post-construction data gathered in 2005 and analysed in this report represents the final stage monitoring programme, thereby fulfilling the FEPA licence requirements.

The species composition of the colony has changed significantly between the baseline and the subsequent construction and post-construction phases reflecting the relative fortunes of the different species. Significantly more Grey seals were present in 2004 than 2003 and in 2005 than 2002 and 2003. This reflects both the national population increase, and the continued increase in the local breeding population, which had a particularly strong breeding season in 2003 (peak count 51 pups). This in itself is most likely to account for the increases in Grey seals using the sandbar on Scroby.

In contrast, there were significantly fewer Common seals hauled out in 2004 than in 2002. Examination of mean, median and peak counts between years also showed that Common seal pup production was notably poor in 2004. The 2005 data was not significantly different from the data collected in 2002 or 2004 suggesting any decline was temporary. However, Common seal counts remained low in comparison to the baseline years (mean counts: 91.4 in 2002, 79.92 in 2003, 52.27 in 2004 and 57.5 in 2005). Low counts could be attributed to a number of factors, including reflection of the national declining trend (with disease outbreaks and cumulative impacts associated with increased anthropogenic disturbance), the impact of severe storms during their breeding season particularly on pup survival, and potential inter-specific competition with Grey seals. Unfortunately, the nature of data gathering means that there is no evidence to support or repudiate any of these factors.

In contrast, the potential for construction related disturbance has been determined at other offshore wind farm sites (e.g. Bockstigen in Gotland, Sweden where significant but temporary reduction in use of haul out sites by Grey seals 1.5 and 2 km away was noted). Indeed, reduced use of Scroby during the construction period was highlighted as being likely in the Environmental Statement. Moreover, the basis for the species-specific response of Common Seals at Scroby is provided by the species being particularly sensitive to disturbance with slightly better hearing than Grey seals, coupled with the apparent habituation of Grey seals at their main haul-out on the southern tip of Scroby to a tourist vessel. Evidence of a causal mechanism was provided by a significant negative correlation between the number of seals hauled out and the number of boats on the wind farm site, although it should be noted that this data cannot be corrected to allow for other potentially influential factors (e.g. wind speed, wind direction and seasonality).

Although the 2005 data implies some recovery from a temporary effect, Common seal counts remain low, and it is recommended that monitoring is continued to confirm and monitor potential improvements back to pre-construction levels. Such recovery time data does not currently exist, and would be of great relevance to other offshore wind farm sites planned near seal colonies (e.g. in the Greater Wash Strategic Area). It is also suggested that vessels visiting Scroby do not pass within 600 m of haul-out sites along the extent of the landward edge of exposed sands in an attempt to minimise any disturbance to Common seals.

CONTENTS **Page**

PLATES

APPENDICES

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 high capacity turbines on Scroby Sands, a dynamic sand bar system approximately 3 km offshore of Great Yarmouth, Norfolk.

The Schedule to Licence states that a monitoring programme for the seals, as agreed with the Sea Mammals Research Unit (SMRU) should be carried out to determine the impact of the wind farm. This is specified in the licence as two fly-overs per month at low water for the six summer months (April to September) pre, during and post construction. Data collected prior to construction in 2002 and 2003 were to establish the baseline conditions against which the potential impacts of the wind farm could be measured. The licence states that the data collected during each fly-over should be copied to SMRU and a written report provided to the Licensing Authority at three monthly intervals (Condition 9.14 of DEFRA Licence 31272/02/0).

ECON were first approached to analyse the first year of baseline data (collected 2002) in April 2003, and have subsequently analysed both the second year of baseline data (2003), and construction data (2003). This report is part of this series of interim reports, and is concerned with analysis of the post-construction data gathered in 2005.

2. BACKGROUND INFORMATION

Table 1 shows the content of previous Scroby seal reports. In brief, the outputs from the two baseline reports (in addition to survey analysis) consisted of a historical review of the colony and several recommendations of additional surveys. Analysis of data from the construction year indicated that both Common seal numbers and recruitment were poor. Information from other wind farm sites near seals (Horns Rev and Nysted) was reviewed, although this work, based around use of satellite telemetry as a means of tackling largely site specific questions, was overall only of minor relevance to the seal monitoring programme at Scroby.

3. AIMS

In summary, the specific aims of this report were:

1. To analyse the data from the 2005 aerial surveys;
2. To compare this data against the baseline data gathered in 2002 and 2003 and the construction data gathered in 2004;
3. To evaluate the current status of the Common seals at Scroby, with particular reference to the potential impacts of construction-related disturbance in 2004.
4. To review current knowledge of the potential impacts of wind farms on seals, and to discuss these in the context of the Scroby Sands wind farm.

Table 1. Summary of previous reports

Years	Stage	Report content	Main findings
2002 & 2003	Year 1 & 2 Baseline data	Historical review of the colony	Used as Common seal haul out for at least a century. Grey seals first identified late 1950s. Both species used to breed on Scroby, when it was more exposed, although Grey seals now breed on the mainland beaches (Appendix I).
		Analysis of 2002 data	Common 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	• 3 additional surveys to be carried out during the pupping period to obtain a more reliable measure of Common seal pup productivity. (*Carried out 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. *(Carried out winter 2004/2005).*
2004	Construction data	Analysis of 2004 data	• Significantly fewer Common seals hauled out in 2004 than in 2002. • Common seal recruitment poor, although severe weather was believed to be at least partially attributable. • A weak negative correlation was found between the number of boats on the wind farm site and the number of Common 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 4 Common & 6 Grey seals. Common seals were identified as potentially the most vulnerable since Grey seals were less site faithful and had greater home ranges. Post-construction data not available at time of writing. • Horns Rev, Denmark: satellite telemetry on 10 Common seals revealed substantial variation in foraging patterns, but did identify some consistently used foraging routes. The seals spent less time in the wind farm area than expected (0.1%), and it was concluded that the site acted rather as a corridor for movements between other foraging areas. The paucity of fixes from within the wind farm area means that it was impossible to evaluate whether construction had any sort of impact.
		Discussion of potential impacts & mechanisms	Identified as: • Disturbance from physical presence of turbines, e.g. moving blades (construction & operation). • Noise (construction & operation) • Disturbance from associated human activity
		Recommendations	Monitoring to continue in order to assess any further changes in Common seal numbers.

4. METHODS

4.1 Aerial survey specifications

The 2005 monitoring took place in the form of aerial surveys conducted at approximately fortnightly intervals throughout the summer months (05/05/05 – 26/10/05).

The aerial surveys were undertaken by Air Images Ltd using a Cessna 150 aerobat aircraft, flying at a height of approximately 1000 ft and at a speed of 80 knots. A series of photographs were taken with a Kodak DCS Pro SLR/n 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 and the time taken to carry them out varied according to weather conditions. Surveys were conducted at low tide, when the sandbank was most visible and the greatest number of seals was present.

The photographs were supplied to ECON as both 20 cm x 15cm prints, and as jpgs scanned in at 300 dpi and 600 dpi for enlargements showing the seals. The photographs were pieced together to form an aerial map of Scroby, with enlarged sections where the seals were hauled out. Table 2 shows the programme of surveys and the specifications of the equipment used (data supplied by Air Images Ltd).

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, were also taken.

The intervals between surveys were generally consistent, although there are some major gaps at the beginning and end of the monitoring programme. The commencement of the surveys was a month late (no April surveys) due to a combination of contractual issues between E.ON and Air Images Ltd and poor weather. The second August survey was not undertaken due to weather problems. However, this was not considered to be too problematic since there was a survey in early September. The last survey was carried out too late (26th October) to be comparable with the data collected in the other years and was therefore excluded in the analysis on the basis of the data gathered in the winter of 2004/2005, which suggested that haul out patterns differed significantly between seasons.

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. These codes are shown in Table 3.

Table 2. Details of the aerial survey programme.

Date & time (BST unless stated)	*Survey interval (days)*	*DGPS points of Scroby (WGS 84)*			*Time of Low Water*
		Location	*Northings*	*Eastings*	
Survey 1, 05/05/05 (12:50)		*N. point*	52°36.755’	001°47.655’	13:35
		Mid point	52°36.138’	001°47.336’	
		S. point	52°35.858’	001°46.764’	
Survey 2, 28/05/05 (12:00)	22	*N. point*	52°36.649’	001°46.517’	12:00
		Mid point	52°36.141’	001°47.318’	
		S. point	52°36.868’	001°47.186’	
Survey 3, 10/06/05 (17:45)	12	*N. point*	52°35.946’	001°46.418’	17:55
		Mid point	52°36.032’	001°47.534’	
		S. point	52°36.741’	001°47.177’	
Survey 4, 21/06/05 (15:00)	10	*N. point*	52°35.713’	001°46.916’	14:54
		Mid point	52°36.029’	001°47.524’	
		S. point	52°36.738’	001°47.139’	
Survey 5, 05/07/05 (15:15). Pupping survey 1	13	*N. point*	52°35.712’	001°46.593’	14:59
		Mid point	52°36.112’	001°47.662’	
		S. point	52°35.748’	001°47.196’	
Survey 6, 10/07/05 (17:45). Pupping survey 2.	4	*N. point*	52°35.875’	001°46.514’	18:14
		Mid point	52°36.276’	001°47.669’	
		S. point	52°35.698’	001°47.183’	
Survey 7, 15/07/05 (09:15). Pupping survey 3.	4	*N. point*	52°36.468’	001°46.579’	09:06
		Mid point	52°36.231’	001°47.658’	
		S. point	52°36.619’	001°47.187’	
Survey 8, 19/07/05 (17:20)	3	*N. point*	52°35.847’	001°47.326’	13:40
		Mid point	52°36.114’	001°47.584’	
		S. point	52°36.785’	001°47.203’	
Survey 9, 31/07/05 (12:50)	10	*N. point*	52°35.629’	001°46.384’	11:59
		Mid point	52°36.114’	001°47.365’	
		S. point	52°36.780’	001°47.228’	
Survey 10, 08/08/05 (18:10)	7	-	-	-	17:48
Survey 11, 05/09/05 (16:55)	31	*N. point*	52°34.960’	001°46.214’	16:45
		Mid point	52°35.807’	001°47.519’	
		S. point	52°35.254’	001°47.399’	
Survey 12, 13/09/05 (11:10)	7	*N. point*	52°35.110’	001°47.726’	10:44
		Mid point	52°36.209’	001°47.483’	
		S. point	52°35.149’	001°47.208’	
Survey 13, 26/10/05 (10:36)	42	*N. point*	52°36.786’	001°47.770’	11:30
		Mid point	52°36.252’	001°47.299’	
		S. point	52°35.830’	001°47.032’	

Table 3. Colour codes used in classification of seals, according to species, sex (Greys only) and age (adults and pups, and young-of-the-year, [YOY] in the case of Greys).

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

The total number of seals and the number of each species present was compared between years. Kruskal-Wallis and Chi-square tests were used to test for any statistically significant differences between 2004 and the baseline years (2002 and 2003).

4.2.2 Breeding success

Pup counts can provide an index of colony productivity, and represent an important means of detecting change (Thompson *et al.* 1997). Consequently three additional surveys were carried out during the peak pupping period (5th, 10th and 15th July) specifically in order to obtain a more reliable measure of colony productivity.

4.2.3 Distribution

In order to map the distribution of seal haul out areas it was necessary to select the best of the two photographic sequences 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 haul-out areas mapped.

5. RESULTS

5.1 Analysis of 2004 aerial survey data

5.1.1 Abundance

A break down of seal counts from each of the 17 surveys are shown in Table 4 with summary statistics provided in Table 5 and Figure 1. Maps of the seals observed on each survey are included as Figures 2-14.

Table 4. Counts from the aerial surveys carried out during 2005.

Survey no. & date	Common adult	Common pup	Total Commons	Grey bull	Grey cow	Grey YOY	Total Greys	Unid. seals	**GRAND TOTALS**
1) 05/05	16	0	16	29	42	9	80	0	**96**
2) 28/05	35	0	35	28	59	4	91	0	**126**
3) 10/06	30	10	40	29	23	7	59	0	**99**
4) 21/06	0	0	0	0	0	0	0	101*	**101**
5) 05/07	61	15	76	43	31	1	75	0	**151**
6) 10/07	39	28	67	50	64	8	122	0	**189**
7) 15/07	47	16	63	44	37	5	86	0	**149**
8) 19/07	81	19	100	30	14	4	48	0	**148**
9) 31/07	86	16	102	36	18	1	55	0	**157**
10) 08/08	67	11	78	22	60	0	82	0	**160**
11) 05/09	77	17	94	33	38	0	71	0	**165**
12) 13/09	18	1	19	1	7	0	8	84**	**111**
13) 26/10	84	0	84	18	40	0	58	0	**142**

*No enlargements of seals included in this survey
** Enlargements incomplete

Table 5. Summary statistics of haul-out counts over the study period.

	2002	2003	2004	2005
Mean haul-out count	150	116	110	138
Maximum count	203	159	304	189
Minimum count	77	66	33	96
Range	126	93	271	113
Maximum pup count	67 (on 4 July)	42 (on 19 Aug)	16 (30 July)	28 (10 July)
Median pup count	4.5	6.5	4	13
Mean pup count	12.3	11.4	6.3	11.1
Common to Grey ratio	5:1	5:1	5:6	5:6
Mean no. Commons	91.4	79.92	52.27	57.5
Median no. Commons	78	79	48	71.5
Maximum no. Commons	167	155	161	102
Mean no. Greys	21.6	9.3	56.6	64.75
Median no. Greys	0	0	58	73
Maximum no. Greys	98	34	143	122

Bearing in mind the high levels of natural variation associated with haul out counts, the 2005 data can be considered similar to the other years in terms of the maximum, minimum and range of seals hauled out. The ratio of Common seals to Grey seals remained similar to that observed in 2004, i.e. showing a predominance of Grey seals rather than Commons (as was observed in the baseline years). However, median Common seal counts were higher in 2005, indicating that Commons were present with greater regularity than in 2004, although the mean values still indicate that fewer Commons were present than in the baseline years. Mean and median Grey seal counts indicate that this species continued to increase throughout 2005.

5.1.2 Breeding success

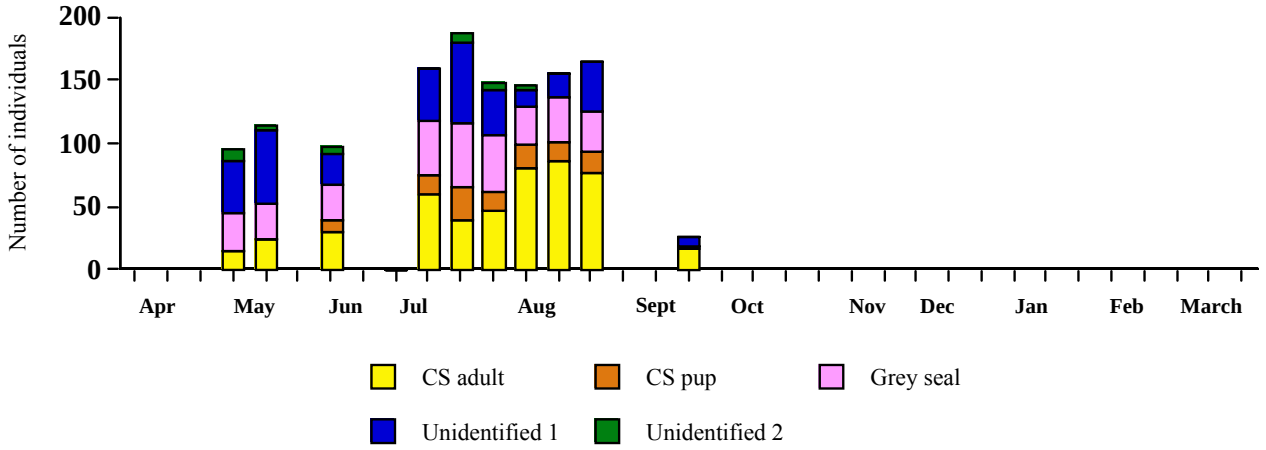
The peak Common pup count (28) was relatively low in 2005, more similar to that observed in 2004 (16) than the more successful years in 2002 (67) and 2003 (42), although comparatively high mean and median pup counts indicated that although numbers were low, pups were consistently sighted on Scroby (Table 5).

Although number of Common seals and pups used the subsidiary sand bar during the pupping period in 2004, this behaviour was not observed in 2005.

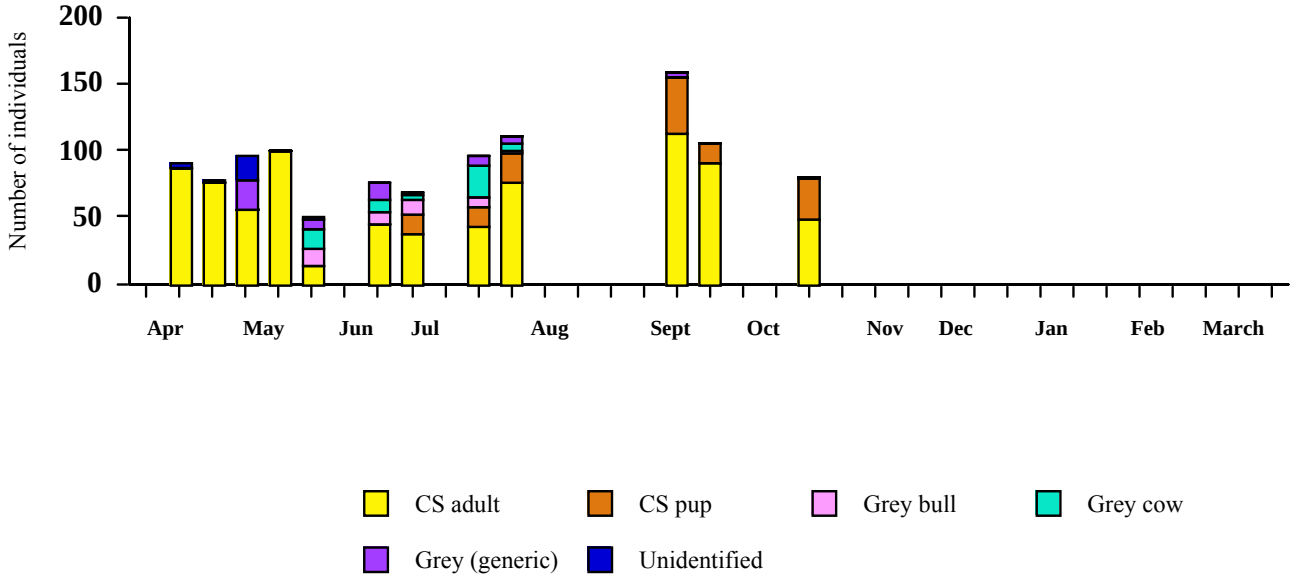
As stated in the 2004 report, Grey seals appear to be breeding with increasing success (Figure 15). An early season count of breeding Grey seals taken from the mainland breeding colony on 04/12/05 indicated healthy pup numbers (39) in spite of high levels of public disturbance.

Figure 1. The number of Common (CS) and Grey seals (with some unidentified) hauled out on Scroby Sands in A) 2002 and B) 2003, and C) 2004 and D) 2005 (overleaf).

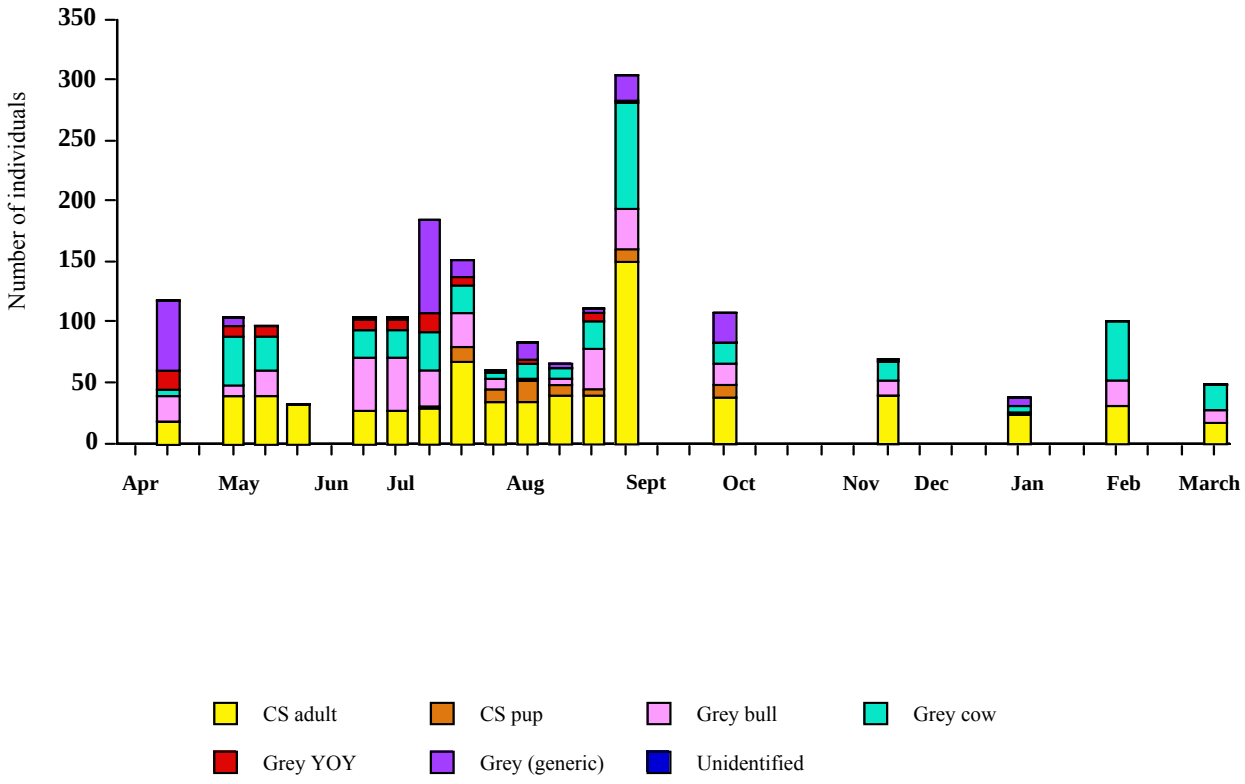
A) 2002



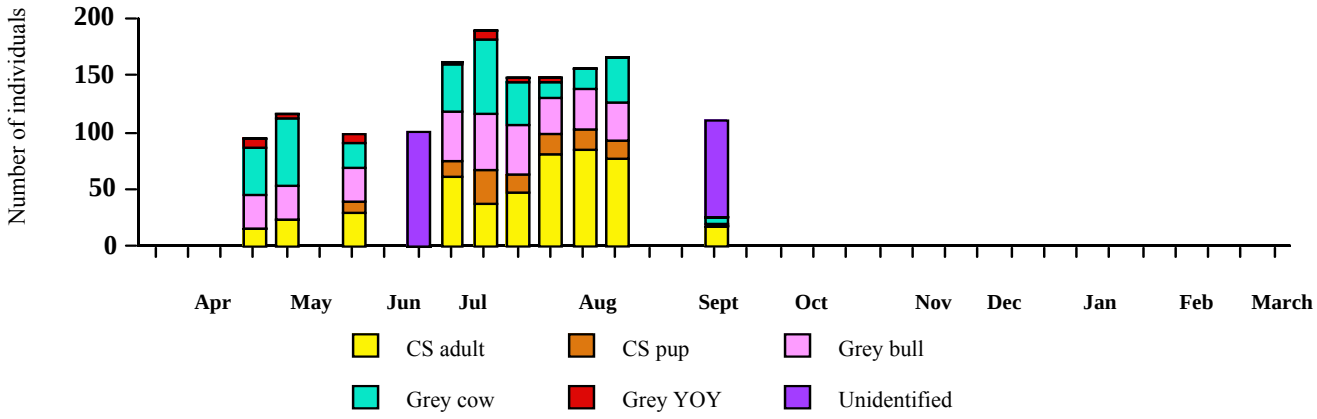
B) 2003

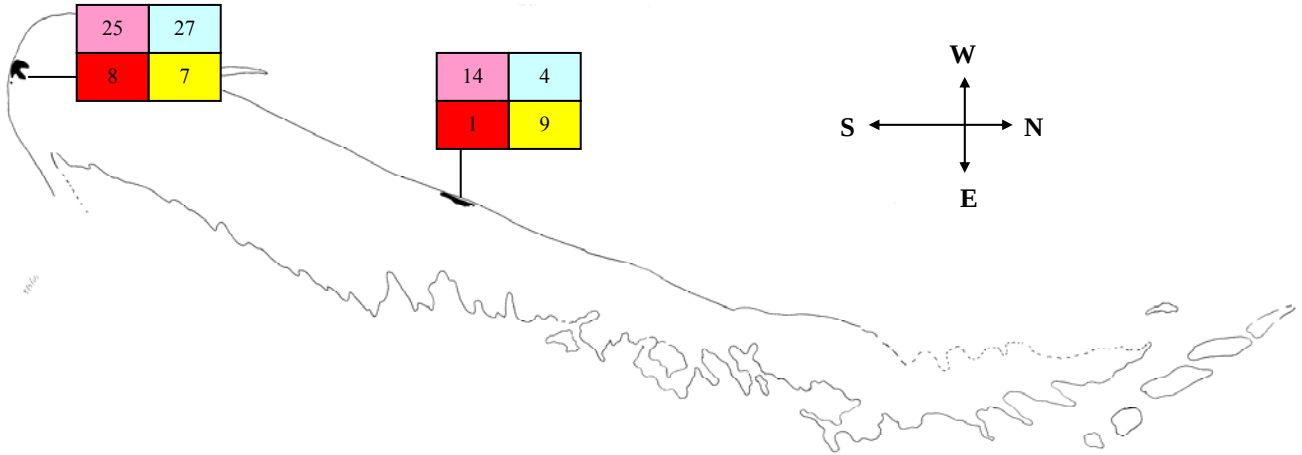


C) 2004


Number of individuals
350
300
250
200
150
100
50
0
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
CS adult
CS pup
Grey bull
Grey cow
Grey YOY
Grey (generic)
Unidentified

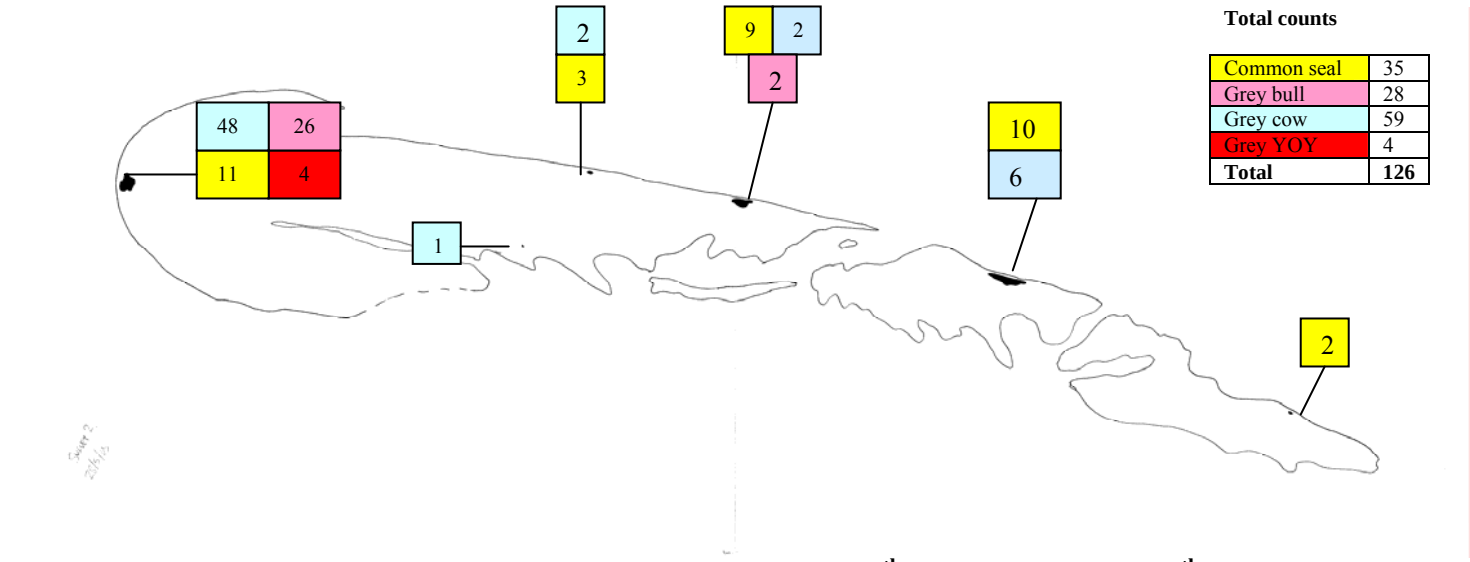
D) 2005


Number of individuals
200
150
100
50
0
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Jan
Feb
March
CS adult
CS pup
Grey bull
Grey cow
Grey YOY
Unidentified



Total counts

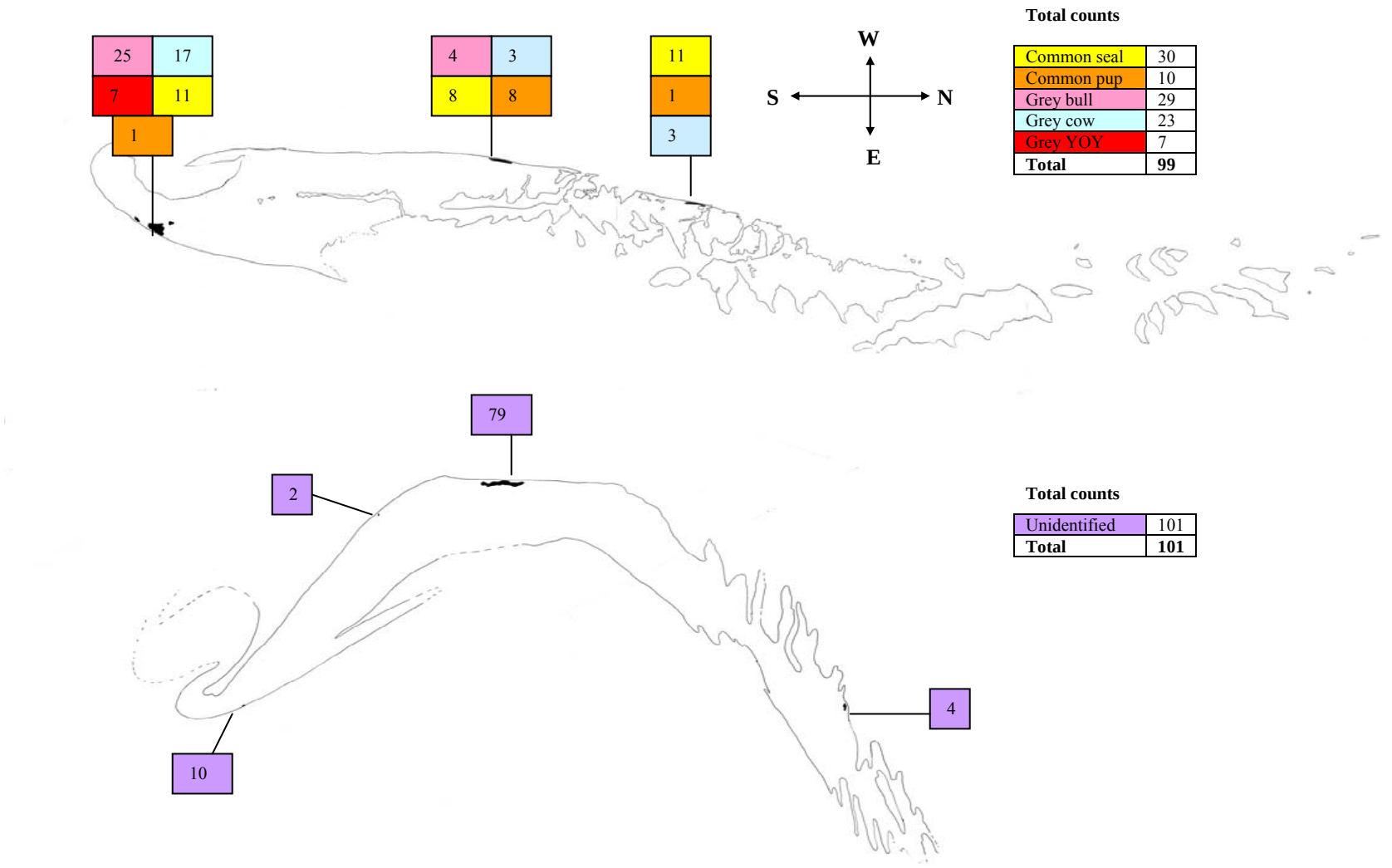
Common seal	16
Grey bull	29
Grey cow	42
Grey YOY	9
Total	**96**



Total counts

Common seal	35
Grey bull	28
Grey cow	59
Grey YOY	4
Total	**126**

Figures 2 & 3. Number and distribution of seals hauled out on 5th May (above) and 28th May (below) 2005.



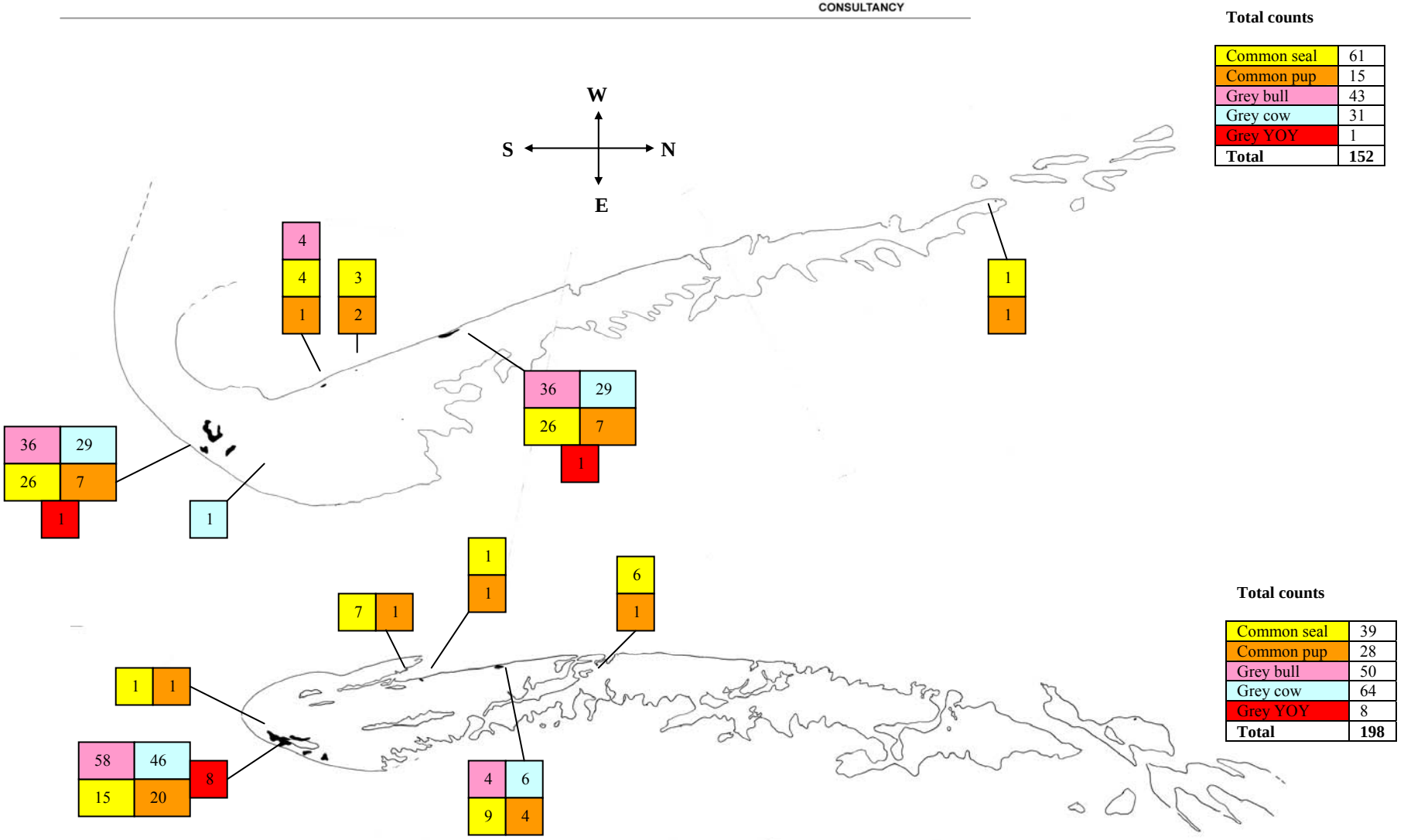
Total counts

Common seal	30
Common pup	10
Grey bull	29
Grey cow	23
Grey YOY	7
Total	**99**

Total counts

Unidentified	101
Total	**101**

Figures 4 & 5. Number and distribution of seals hauled out on 10th June (top) and 21st June (bottom) 2005.



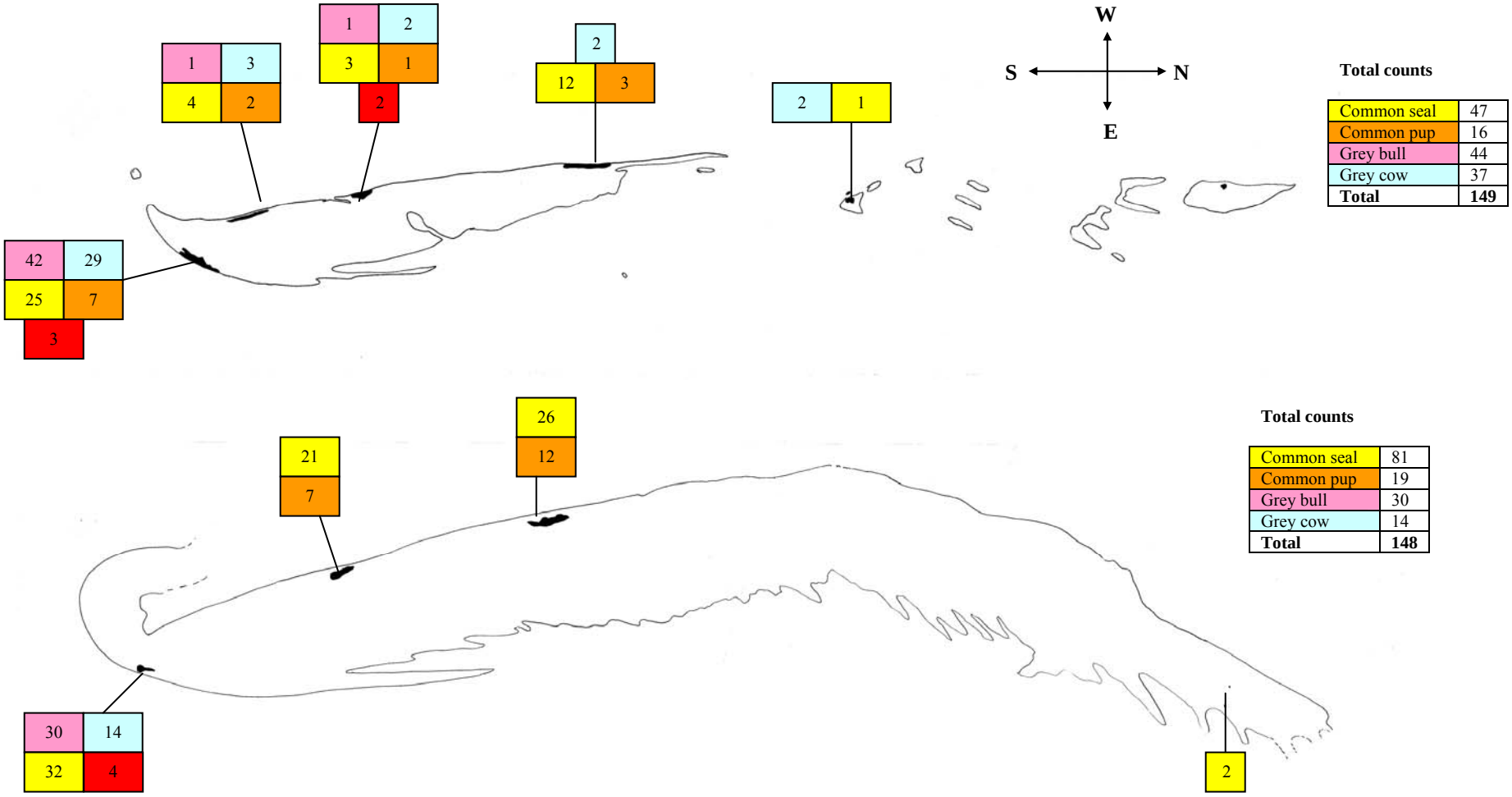
Total counts

Common seal	61
Common pup	15
Grey bull	43
Grey cow	31
Grey YOY	1
Total	**152**

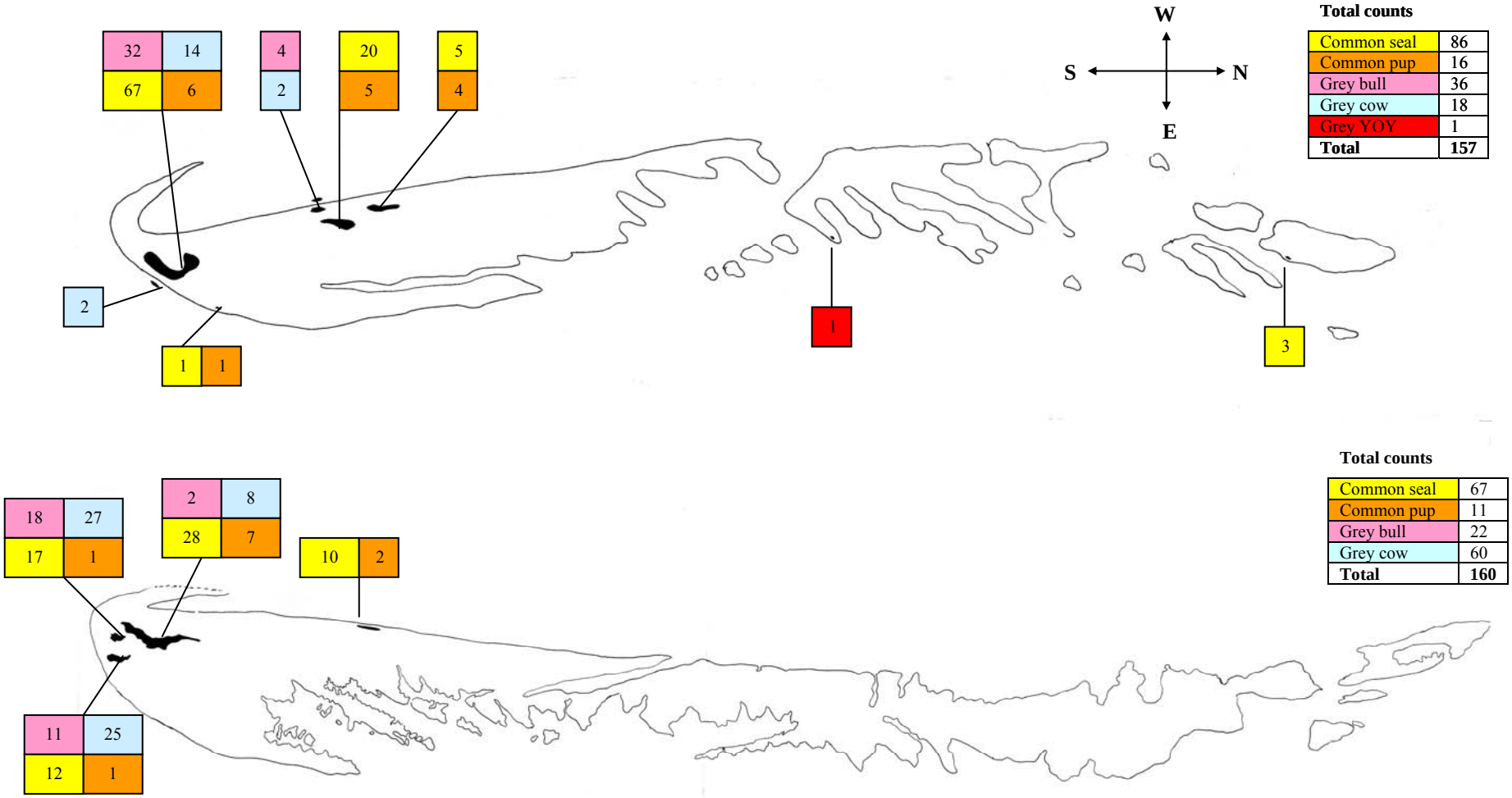
Total counts

Common seal	39
Common pup	28
Grey bull	50
Grey cow	64
Grey YOY	8
Total	**198**

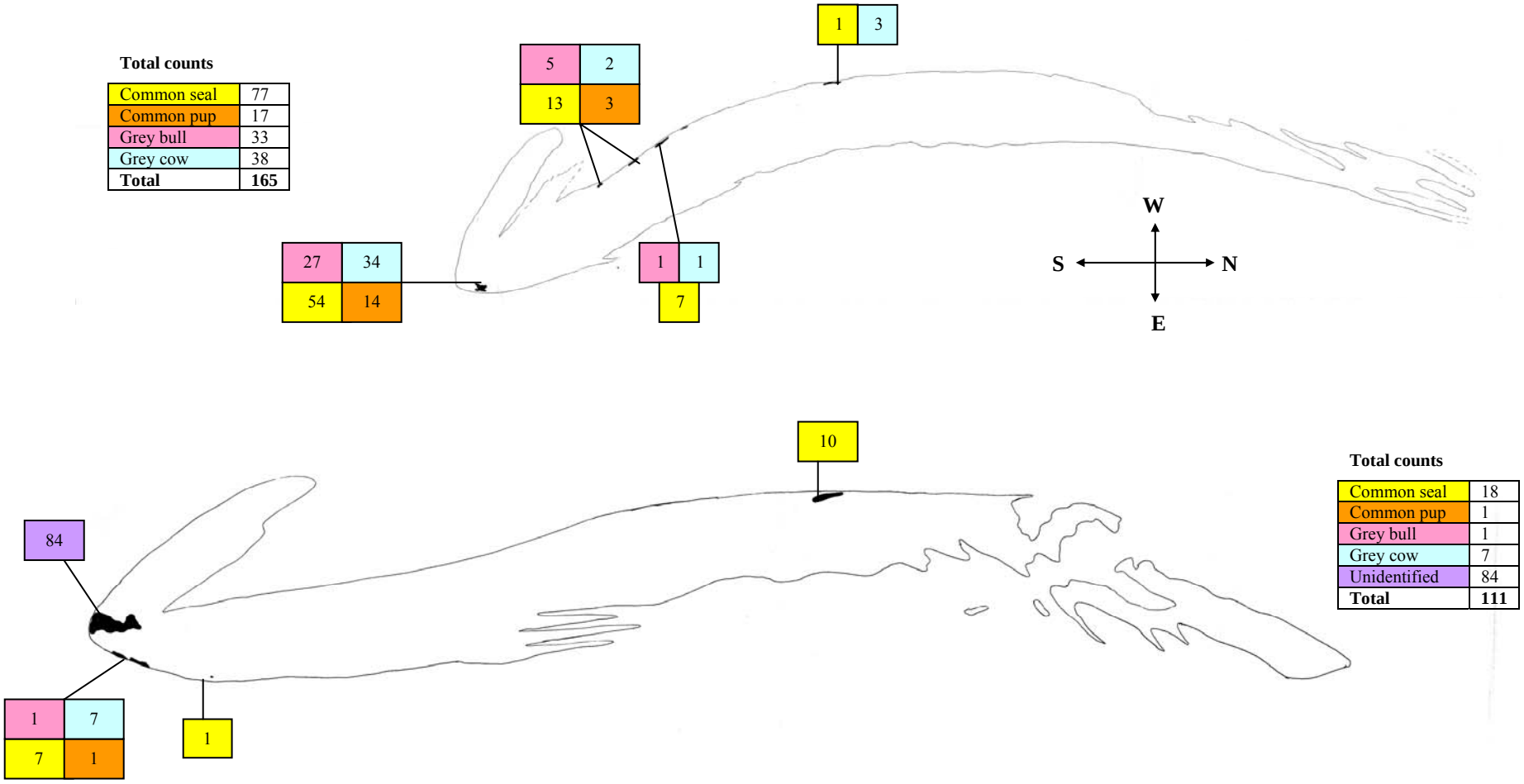
Figures 6 & 7. Number and distribution of seals hauled out on 5th July (above) and 10th July (below) 2005.



Figures 8 & 9. Number and distribution of seals hauled out on 15th July (above) and 19th July (below) 2005.



Figures 10 & 11. Number and distribution of seals hauled out on 31st July (above) and 8th August (below) 2005.



Figures 12 & 13. Number and distribution of seals hauled out on 5th September (above) and 13th September (below) 2005.

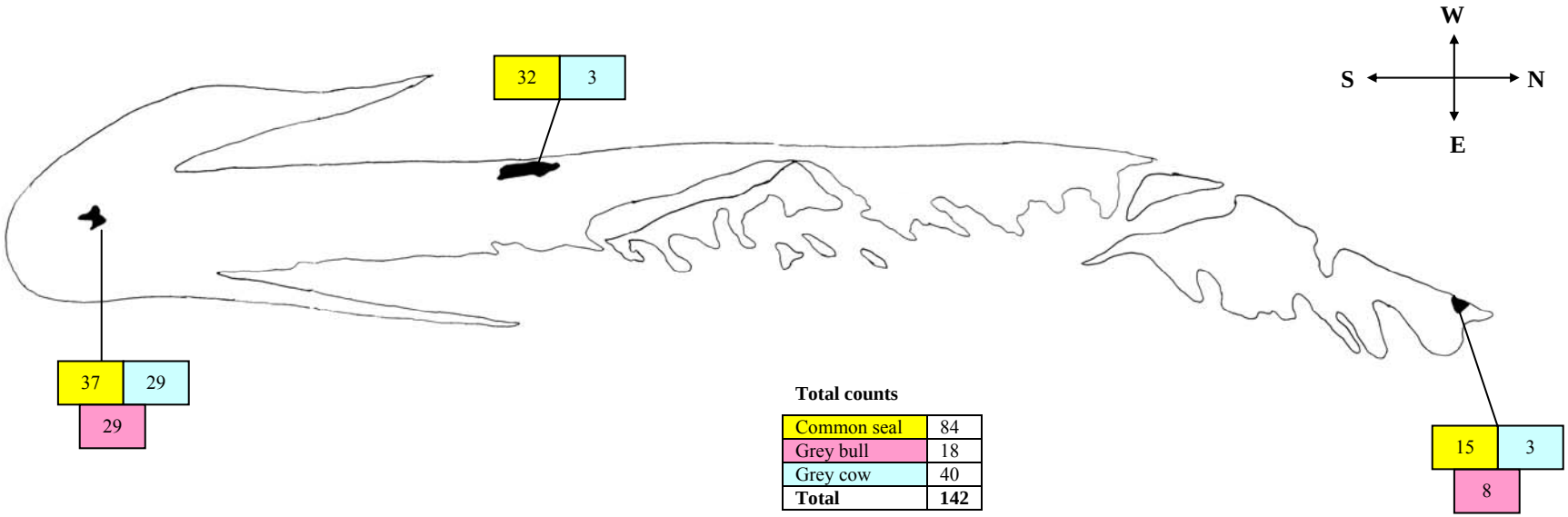
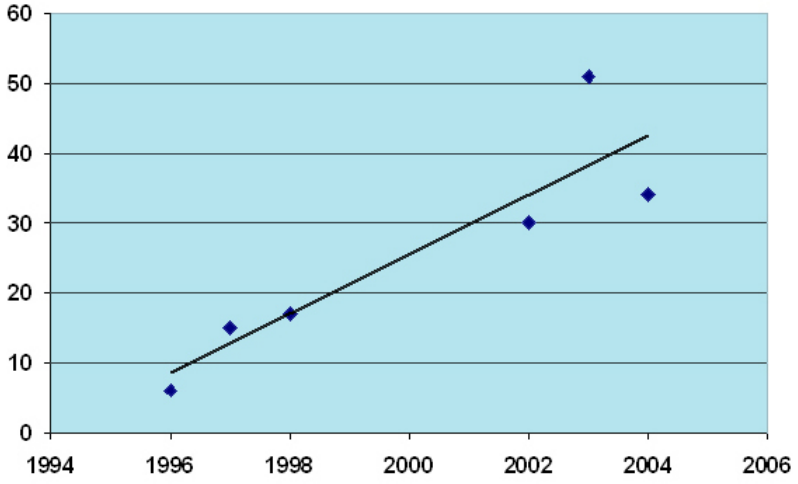


Figure 14. Number and distribution of seals hauled out on 26th October 2005.

Figure 15. Peak Grey seal pup counts taken in winter from the Horsey-Winterton breeding colony with trend line. (1996-1999 counts from Norfolk Bird & Mammal Reports, all other data from ECON).



5.1.3 Distribution

In order to assess how the distribution of seals had changed between years, the number of times seals occurred in different areas (frequency occurrence) was plotted (Figure 16).

Whilst the maps show that there is a substantial amount of inter-annual variation, the SE appears to be used with a high degree of frequency throughout. Although haul out groups are frequently mixed, this site appears to be dominated by Grey seals. Seals also use the west side of the bank on a regular basis, predominantly the SW in 2002 and 2005 and the NW in 2003 and 2004. These haul out groups are more dispersed and are generally principally composed of Common seals. Plate 1 shows the location of these two main groups.

Although the most favoured sites were used in all years, general distribution patterns have changed through time. In 2002, seals almost exclusively used the southern half of the sands, whereas in 2003 seals started to haul out in the NW. It was during this year that the second subsidiary sandbar (Plate 1, Figure 16) appeared, and it is possible that this additional sandbar provided a more sheltered and desirable haul out area. Indeed, in 2004 seals started to haul out on the subsidiary sandbar itself, especially Common seal cows (both pregnant and with pups). It is likely that the sands were highest and most exposed during this year, since this is the only year in which all parts of Scroby are used. In 2005 haul out patterns appear to be more similar to 2002, with seals concentrated in the southern part of Scroby.

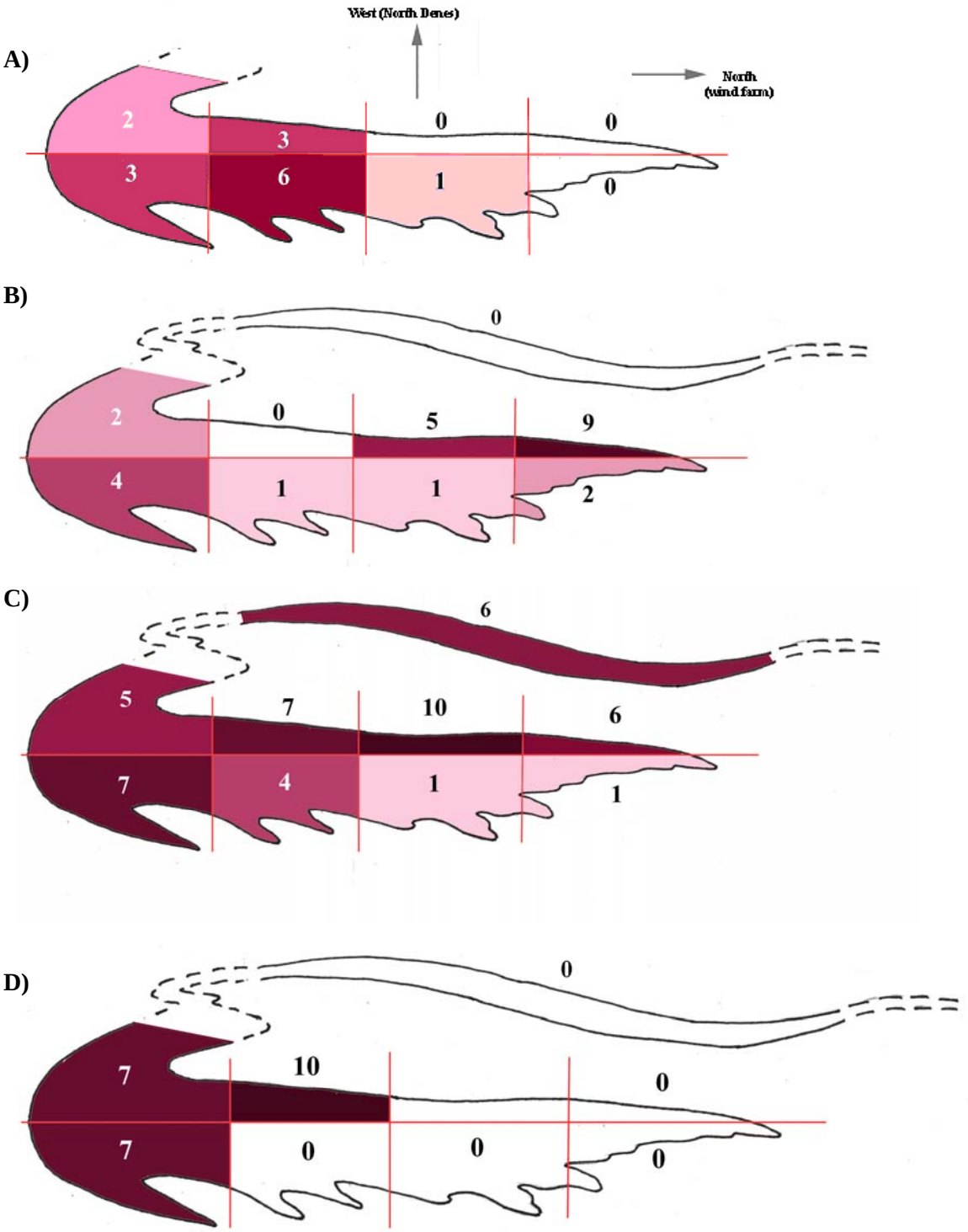


Figure 16. **Frequency occurrence of seals in each area in A) 2002, B) 2003, C) 2004, and D) 2005.**

Plate 1. Location of the two main seal haul out areas.

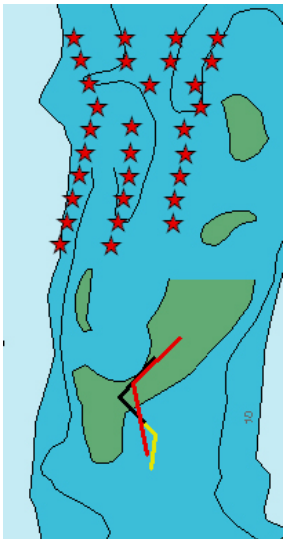
Since the sand exposed at each low tide varies substantially (Figures 2-14), 3 GPS points describing the extent of the visible sandbar were plotted for each survey occasion so that variation in length and location of the sands could be assessed (Figures 17 & 18). These plots reveal that Scroby is in general further south in 2004 than in 2005 and that sand is building up to the west (visible on Plate 1).

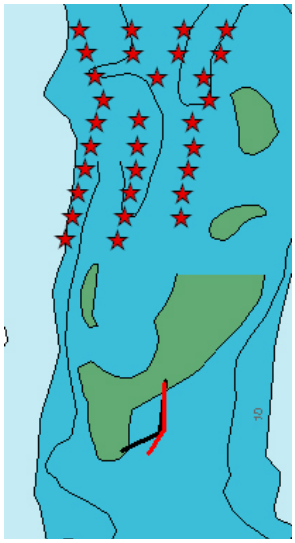
5.2 Statistical treatment

Kruskal-Wallis tests revealed a statistically significant difference in the total number of seals hauling out on the sands between years, although post-hoc comparisons did not detect a significant difference between any one year and any other (Table 6). There were significant differences in the numbers of both Common seals ($n=48$, $\chi^2 = 10.759$, $df=3$, $p<0.05$) and Grey seals ($n=48$, $\chi^2 =17.05$, $df=3$, $p<0.01$). A post-hoc comparison revealed significantly ($p<0.05$) lower Common seal numbers occurred in 2004 than 2002, and significantly higher ($p<0.05$) Grey seal numbers in 2004 than 2002, and in 2005 than 2002 and 2003 (Table 6).

There were no inter-annual differences in Common seal pup numbers using data from July and August surveys, when pups occur with greatest frequency.

Figure 17. **Location of Scroby Sands on each survey carried out in 2004 plotted from north, south and mid GPS points collected by Air Images Ltd. The position of individual turbines is shown by red stars.**



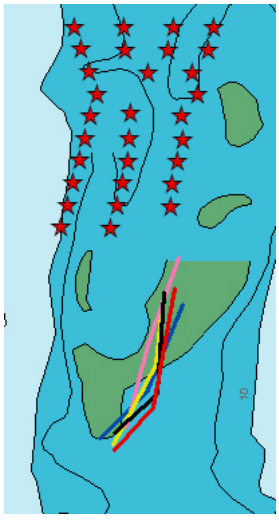


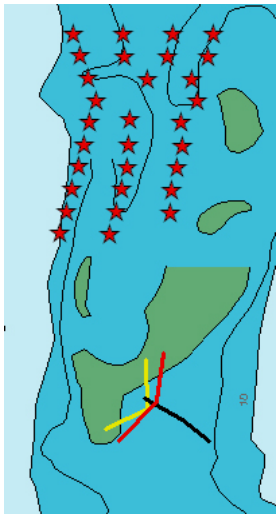
Apr & May

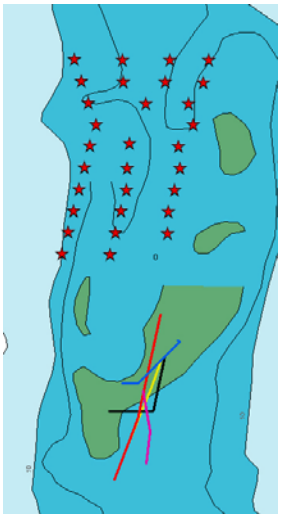
	19/04
	21/05
	31/05

June

	11/06
	30/06







July

	02/07
	06/07
	10/07
	15/07
	30/07

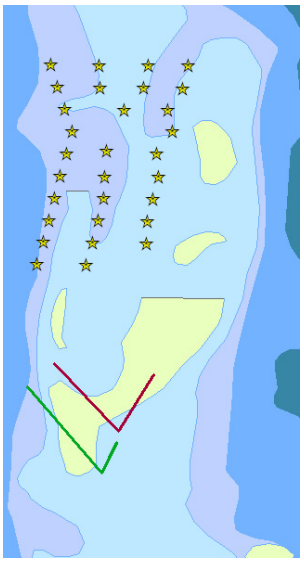
Augt & Sept

	17/08
	29/08
	10/09

Oct - March

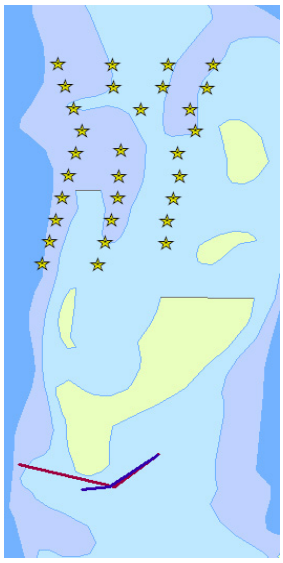
	05/10
	27/11
	08/01
	04/02
	08/03

Figure 18. Location of Scroby Sands on each survey carried out in 2005 plotted from north, south and mid GPS points collected by Air Images Ltd. The position of individual turbines is shown by yellow stars.



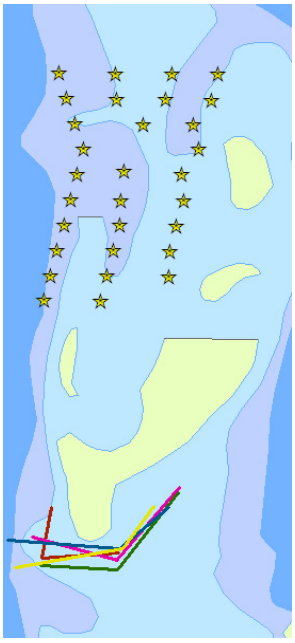
May

	05/05
	28/05



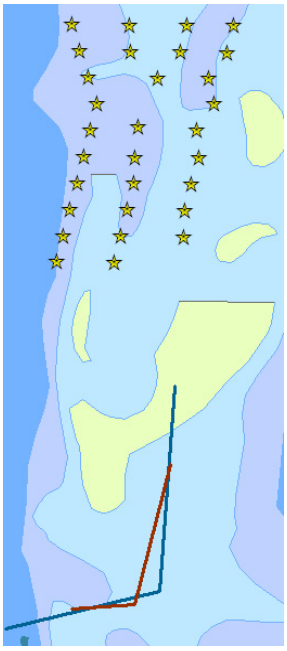
June

	10/06
	21/06



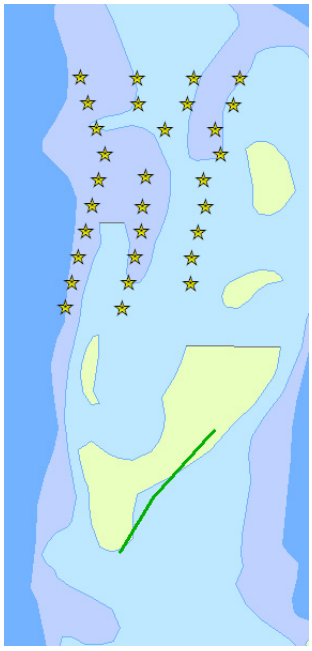
July

	05/07
	10/07
	19/07
	31/07



Sept

	05/09
	17/09



Oct

	26/10

Table 6. Results of Kruskal-Wallis tests for differences in the numbers and species of seals hauling out at Scroby Sands.

Test	N	df	Chi-square	Probability & significance	Location of differences
Total number of seals	10^a, 12^b, 14^c, $12^d = 48$	3	9.265	0.026*	-
Common seals	10^a, 12^b, 14^c, $12^d = 48$	3	10.759	0.013*	2002>2004
Common seal pups*	4^a, 3^b, 7^c, $6^d = 20$	3	6.827	0.078^{ns}	-
Grey seals	10^a, 12^b, 14^c, $12^d = 48$	3	17.054	0.001**	2005>2002 2004>2003 2005>2003

[a] 2002 [b] 2003 [c] 2004 [d] 2005 ns=not significant, * = p<0.05, ** =p<0.01, *** = p<0.001
* Data from July and August surveys when pups occur with greatest frequency and in peak numbers.

A Chi-square test confirmed that the proportions of Common to Grey seals varied significantly (p<0.001) with the difference lying between the baseline years and 2004 (Table 7).

Table 7. Results of Chi-Square test for species composition change in seals hauling out at Scroby Sands.

Year	Actual values (totals)			Expected values		df	X^2	Significance
	Common	Grey	Total	Common	Grey	3	840.68	***
2002	914	216	1130	789.6312	340.3688			
2003	959	112	1071	748.4027	322.5973			
2004	723	791	1514	1057.966	456.0339			
2005	614	777	1391	874.483	516.517			
Totals	3210	1896	5106	3210	1896			

ns=not significant, * = p<0.05, ** =p<0.01, *** = p<0.001

5.3 Other seal observations

Observations of seals made during the Little Tern monitoring in 2005 are included as Table 8. A total of 187 seals were observed, with fewer Common seals (37) seen than Greys (80). This reflected a similar species composition to that observed during the aerial surveys.

Table 8. Details of seals observed during the various components of the Little Tern monitoring.

Date	Time	Species	Count	Activity & Location	Notes	Occasion
02/05/2005	13:05	Grey seal	1	Hauled out on bank	Bull	Trawl
02/05/2005	13:05	Grey seal	1	Hauled out on bank	Cow	Trawl
30/05/2005	10:32	Seal sp	15	Hauled out on bank		Trawl
30/05/2005	14:50	Common seal	1	Offshore - California		Trawl
26/05/2005	11:26	Grey seal	1	Offshore – North Denes		North Denes foraging obs.
04/06/2005	8:18	Grey seal	1	Hauled out on bank		Trawl
17/06/2005	13:55	Common seal	1	Offshore - Winterton		Telemetry
21/07/2005	15:37	Common seal	35	Hauled out on bank		Trawl
21/07/2005	15:37	Grey seal	35	Hauled out on bank		Trawl
02/07/2005	10:20	Seal sp.	55	Hauled out on bank		Trawl
02/07/2005	15:44	Grey seal	1	Offshore - Horsey		
11/07/2005	14:20	Grey seal	40	H Hauled out on bank		Telemetry

6. DISCUSSION

6.1 Changes in abundance

Significantly fewer Common seals were observed in 2004 than in 2002. Counts from 2005 were not significantly different to any of the other years, although comparison of mean counts indicated that the number of Common seals hauled out were still low in comparison with the baseline data (mean counts: 91.4 in 2002, 79.92 in 2003, 52.27 in 2004, and 57.5 in 2005). Low Common seal numbers thus coincided with the periods of wind farm construction (2004) and operation (2005) respectively.

However, assessing the relative influence of wind farm construction against a background of other influential factors that have not been monitored is both speculative and subjective. For example, declines in Common and increases in Grey seal populations are representative of national trends (SCOS, SMRU 2004), and it could be argued that similar data would have been obtained had the wind farm not been built. This statement is supported by the mean Common seal counts, which decrease year on year from 2002 to 2004. There are a number of possible scenarios behind such a decrease; for example the drop between 2002 and 2003 could be attributable to PDV which resulted in a 22% mortality of Common Seals in the Wash (Thompson *et al.* 2005). However, this does not explain the continued decline from 2003 to 2004. Alternatively the potential for inter-specific competition between species could also be important. It is known that the two species compete for prey in some areas, and that Grey seals are at a competitive advantage being able to dive deeper and forage further afield (Thompson *et al.* 2001). However, there have not been any specific studies carried out on this potential competitive relationship.

If the decline in Common seal numbers was linked to wind farm construction/operation then the most likely mechanism by which this could occur is through increased disturbance, the possibility of which was highlighted in the Environmental Statement (Harwood 2001). Since Common seals are known to be more sensitive to disturbance than Grey seals and have slightly better hearing (Edwards *et al.* 2005), the mechanism could potentially account for the differences observed between the two species. Although it was anticipated that the seals at Scroby would be habituated to boat traffic, since they are visited daily in the summer months by a tourist vessel, it should be noted that only Grey seal haul out site is visited (Plate 1). Whilst these Grey seals are almost certainly habituated to the presence of this vessel, it is also possible that they may be subject to novel disturbances in the form of larger, unfamiliar and noisier vessels. Moreover, it is anticipated that the Common seals using the other side of the bank (Plate 1) would be especially vulnerable to such disturbance. Monitoring at Bockstigen offshore wind farm in Sweden confirmed that even Grey seals were sensitive to increases in boat activity (Box 1). In contrast no construction related impacts were observed at either Nysted Offshore Wind farm (Box 2) or Horns Rev. At the former boats were required to keep a specified distance from the seals, whilst at the latter construction related impacts could not be properly assessed since use of the site by seals was so small. Although the avoidance distances at Nysted were not stated in the report, work on the response of Common seals to cruise ships in Alaska indicates that approach distances of up to 600m are unlikely to result in significant disturbance (Jansen *et al.* 2003).

The potential impacts of boats on Common seal numbers at Scroby was shown by the significant negative correlation between the number of boats on the wind farm site seen during aerial surveys and the number of Common seals on the sandbar, using data from all years of the monitoring programme (Spearman Rank Correlation $r_s = -0.457$, $n=44$, $p<0.005$). This was not significant using data from 2004 only. However despite small sample size (n=11) the crudity of the measure (e.g. previous boat activity before the survey, which could determine haul out pattern, was not known), and the lack of correction for other influential factors (e.g. wind speed and direction – TSEG 2003) there was a tendency towards a negative relationship (Figure 19). This contrasted with the relationship between Grey seals and boats (Figure 20) in line with the expected species specific difference in response.

The only way to scientifically test the true effect of boat related disturbance is by adopting a more experimental approach, controlling for other influential factors, as was undertaken at Bockstigen (Box 1). Without this the conclusions from Scroby must remain tentative, and a precautionary approach to the potential for construction related disturbance must be adopted. since it is not possible to assess the relative influence of wind farm construction against the other influential factors that have not been monitored.

For the most part the impacts of prolonged disturbance are likely to be largely metabolic. It is thought that seals generally haul out to rest since less energy is required to maintain body temperature on the land compared to in the water (Bonner 2004). Possible physiological responses to disturbance are likely to include increased heart rate, adrenalin production, and emergency flight responses, although as yet no work appears to have been carried out in this area. Were disturbance events frequent enough, it is conceivable that metabolic expenditure might outweigh the potential gains associated with hauling out.

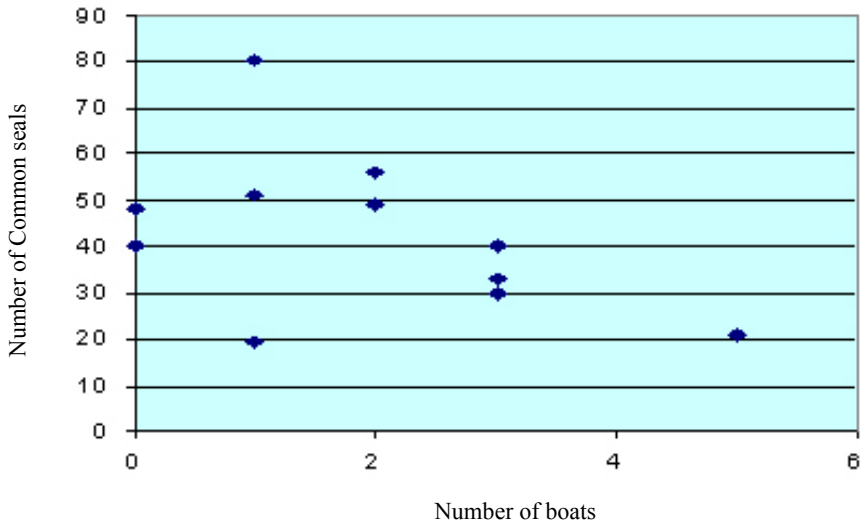


Figure 19. **Number of Common seals hauled compared to the number of boats on the wind farm site.**

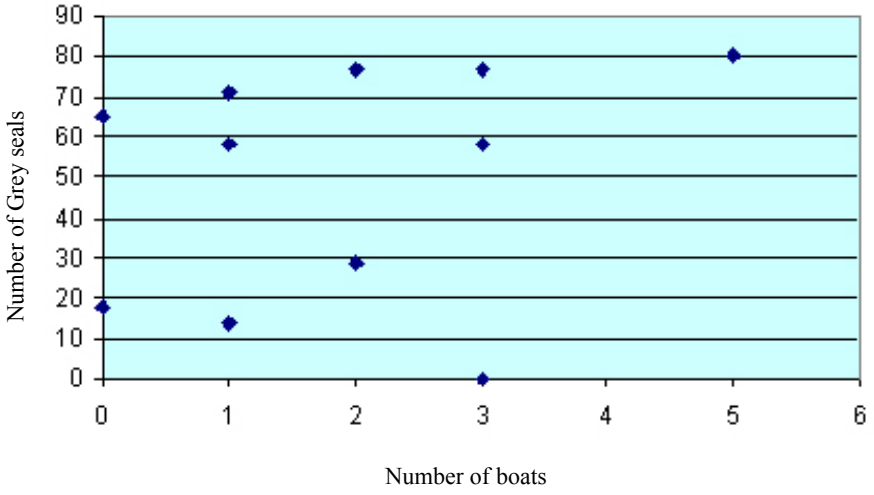


Figure 20. **Number of Grey seals hauled out compared to the number of boats on the wind farm site.**

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 period 10/06/99-10/07/99. 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.

Recent reports:

Sundberg, J., & Søderman, M. (2000). Windpower and grey seals: An impact assessment of potential effects by sea-based windpower plants in a local seal population.

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 Common 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 Common 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 all local haul out sites were carried out to determine seal preferences and 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 was used 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 was undertaken to assess both seasonal variation in haul out patterns, and also to allow data to be gathered on other significant factors, which were found to include 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 Common 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.

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).
- Common 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 Common 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.

Reports:

Edrén, S.M.C., Teilmann, J., Dietz, R., Cartensen, J. (2004). Effect from the construction of Nysted offshore wind farm on seals in Rødsand Seal Sancturary based on remote video monitoring. Technical report to Energi E2 A/S. Ministry of the Environment, Denmark.

Dietz, R., Teilmann, J., Henriksen, O.D. & Laidre, K. (2003). Movements of seals from Rødsand seal sanctuary monitored by satellite telemetry: relative importance of the Nysted Offshore Wind Farm area to the seals. NERI Technical Report No. 429.

Tougaard, S., & Tougaard, J. (2003). Use of the North Sea by Harbour Seal with special emphasis on the Horns Reef area: test of prototype GPS/GSM-transmitter on harbour seals in the Sealarium, Esbjerg. Annual Status Report to Elsam Engineering A/S.

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.
- 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.
- Common seals are the dominant species although Grey seals occur too.

Monitoring Programme:

The monitoring programme consisted of satellite telemetry carried out on 10 Common 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 actually 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 that assessing the impacts of construction was not possible. Therefore it was tentatively concluded that wind farm construction would be unlikely to have any impacts.

The results of the study revealed that the Common seals around Horns Rev travelled over considerably larger distances than the Common seals tagged near Nysted (Box 2), 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.

Reports:

Tougaard, J., Ebbesen, I., Tougaard, S., Jensen, T., and Teilmann, J. (2003). Satellite tracking of Harbour Seals on Horns Reef: Use of the Horns Reef wind farm area and the North Sea. Report to Techwise A/S March 2003.

Tougaard, S., & Tougaard, J. (2003). Use of the North Sea by Harbour Seal with special emphasis on the Horns Reef area: test of prototype GPS/GSM-transmitter on harbour seals in the Sealarium, Esbjerg.

Website:

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

Disturbance may be of crucial importance to pregnant cows, since the additional stress may cause abortion or stillbirths, especially if flushed when heavily pregnant. Cows are already limited by the tide as to when they can give birth, and Common seal pups cannot swim for their first hour or two and may be too weak to last until the next low tide if time with their mother is cut short (Hewer 1974). Increased disturbance is also likely to deter moulting seals, which look to spend as long as possible hauled out (Thompson *et al.* 1989), and may generally decrease the value of the site as a pre-breeding/breeding site (Hewer 1974).

6.2 Changes in breeding success

The number of Grey seal pups produced per year has been steadily increasing since the early 1990s when regular counts started to be taken (Figure 15). This reflects national trends, and is probably due to a combination of increased survival due to use of the mainland instead of Scroby, and increased survival on the mainland due to reduced persecution.

Although Common seal pup counts were not significantly different between years, examination and interpretation of mean, median and peak counts suggested that 2004 appeared to be less successful than the other years (Table 9).

Table 9. Interpretation of mean, median and peak Common seal pup counts during the monitoring period.

Year	Mean	Median	Peak	Interpretation
2002	12.3	4.5	67	Obvious peak, high mean, low median (dispersal of young?)
2003	11.4	6.5	42	Less obvious peak, stable mean and medians indicate regular presence of pups.
2004	**6.3**	**4**	**16**	**All values poor – indicates few pups on Scroby in this year.**
2005	11.1	13	28	Low peak, but high means and medians indicate presence of pups.

Although the pupping period in 2004 coincided with construction, and poor production could conceivably be linked to disturbance by boats and consequent abortion of cows, as was suggested by the Winterton Seal Sanctuary (Daily Mirror article 6 June 2005, British Wildlife, September 2005 and interview for BBC Look East 31 May 2005), this is unlikely for several reasons. The main factor likely to be responsible for the large number of pup deaths reported by the Winterton Seal Sanctuary was the unusually severe storms that coincided with the critical Common seal breeding period (7-8th July). A record mean hourly wind speed of 37 knots (highest since digital records began in 1995) was recorded at Donna Nook, Lincolnshire (nearest recording station to Scroby) (http://wiseweather.co.uk – follow link for Weather extremes for 2004/5, http://www.metoffice. com/climate/uk/interesting/7 8july 2004. html).The severity of these storms alone could account for poor pup production, and certainly these and earlier storms in late June badly affected many of the north Norfolk bird colonies; for example at Scolt Head at least 15 broods of Little tern, 250 broods of Common tern *Sterna hirundo*, 1000 broods of Sandwich tern *Sterna sandvicensis* and 100s of Black-headed gulls *Larus ridibundus* were killed by the storms (Lawton, 2005). It is known that the Scroby Common seal colony frequently has a high mortality rate due to harsh weather conditions, and this is referred to in the historic records from the Norfolk and Norwich Naturalists' Society, who on visiting Scroby observed Greater Black-

backed gulls *Larus marinus* feeding on the carcasses of Common seal pups following severe storms in a number of years (see entries for 1960, 1961, 1962 and 1966 in Appendix I). It is also possible that general pup production was low because the numbers of cows using the site were low, due to potential construction related disturbance. It is therefore most likely that the individuals that were potentially displaced simply gave birth at haul out sites elsewhere.

6.3 Changes in distribution

Activities concerned with wind farm construction itself do not appear to have influenced the area of Scroby used by seals. Indeed patterns appear to be similar between 2003 and 2004, with increasing use of the NW (nearer the wind farm). It is thought that increased use of this area is likely to be due to increased sandbank height and improved shelter from the second subsidiary sandbar. The changes in the distribution of seal haul out sites are most likely to be associated with changes in the sandbank and in particular sandbank height, which ultimately determines the length of time that seals can haul out for (TSEG 2003).

6.4 Evaluating the monitoring programme at Scroby

The Scroby monitoring programme has fulfilled and by far exceeded the FEPA licence requirements, with regular aerial surveys providing a good indicator of number and species using the site. However, other types of monitoring such as satellite telemetry, behavioural observations and remote video monitoring have been used at other sites to answer a range of different questions (Boxes 1, 2 and 3). So how good is the data from the monitoring programme at Scroby compared with that gathered at other sites?

At Nysted the main impact appeared to be a reduction in numbers during pile driving. However, monitoring during pile driving was not carried out at Scroby, since the licence only required surveys in the summer months, although anecdotal evidence suggests that the seals were displaced and appearing some distance away to the south.

The Scroby aerial surveys revealed reduced Common seal counts during construction, as did the monitoring programme at Bockstigen, which consisted of both counting the seals (direct observation) and specific experiments with flush distance and boat activity. Whilst both methodologies are capable of picking up changes in number of seals, the combination of counts and experimental data gives some insight into the mechanism behind the change and potential quantification of impacts (e.g. flushing distance, recovery time after flushing). The Bockstigen monitoring was also more robust as it corrected for other influential factors such as wind speed, direction and seasonality.

Satellite telemetry has been used at Nysted and Horn's Rev to ascertain both the importance of the wind farm area to seals and whether use of this area is reduced during wind farm construction and operation. Although there have been a number of technical problems associated with this technique, the most obvious being 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). Ultimately there were too few fixes from within the wind farm area in both cases for changes in the use of this area to be assessed, although the data did show that Common seals behaved differently between sites, the seals at Nysted having a smaller home range and being ultimately more dependent on the local area than the Common seals at Horns Rev, which travelled further afield apparently using the site

as a 'corridor' to other foraging areas. This data indicates that seal behaviour and use of an area is highly site specific. Despite its limitations, satellite telemetry remains the only way of assessing the value of an area to seals and whether potential habitat loss is a significant issue.

7. CONCLUSIONS & RECOMMENDATIONS

7.1 Scroby

The 2005 monitoring programme was successfully carried out fulfilling the FEPA licence requirement for pre, during and post-construction monitoring. The following significant changes were detected:

Common seals

- Fewer Common seals hauled out in 2004 compared to 2002.
- Some evidence that 2004 was a particularly poor breeding season.

Grey seals

- Significantly more Grey seals hauled out in 2004 than 2003 and 2005 than 2002 and 2003, potentially associated with the increasing productivity of the mainland breeding colony.

It is possible that the reduction in Common seal counts and their poor breeding success in 2004 was related to wind farm construction, which took place at this time. The most likely mechanism is through disturbance associated with increased boat traffic and anthropogenic activity. However, there is no conclusive evidence that this is the case, and a number of other factors may also to be implicated.

Recommendations:

- **Monitoring to continue in 2006**
  Despite naturally high variability in haul out counts the 2005 Common seals counts indicate that numbers have ceased to decline perhaps with some recovery. However, mean Common seal counts still remain low in comparison with the baseline years, and it is strongly recommended that monitoring continues in 2006 to confirm that any impacts were temporary and to rule out concern of a longer-term impact on Common seals. This would complete a balanced design of 2 years pre-construction, 1 year construction, and 2 year post-construction data collection as was adopted for Little Terns.

- **Minimization of maintenance related disturbance**
  There is some evidence that Common seals hauled out are disturbed by additional boat traffic probably associated with construction/maintenance. It is recommended that boats take a route to the wind farm that does not pass within 600 m of the sandbank as per the recommended distances in Jansen *et al.*(2003).

7.2 Future Sites

Conclusions

- Anecdotal evidence from Scroby and observational data from Bockstigen indicates that pile driving has a significant negative effect on the number of seals (both species) hauling out. It is not known whether seals chose not to haul out, or actively move out of the vicinity, though the latter seems likely.
- The results so far indicate that the greatest impacts of wind farms on seals relate to the construction phase, although potential long term and cumulative effects could yet occur.
- As yet there is no evidence that operational wind farms have any impacts on seals (Boxes 1, 2, & 3). Recent work carried out on subacoustic noise also suggests that levels will be largely insufficient to cause disturbance (Nedwell & Howell 2004).

Recommendations:

- Use of satellite telemetry (or GPS/GSM technique) to assess how seals use the greater area & the relative importance of the proposed site (baseline studies). Comparison of data from Nysted and Horn's Rev indicates that the home range and foraging behaviour of seals can vary considerably between sites.
- Consideration of the likely displacement impacts during pile driving, which should not be carried out during the breeding season, and should employ the use of use of seal scrammers and porpoise pingers to deter seals and porpoises from the site in order to avoid causing hearing damage. Seals should be monitored during this period so that response times can be ascertained.
- Minimization of disturbance associated with additional boat traffic and construction & maintenance related activities (use appropriate vessel routes, avoid carrying out noisy procedures during breeding period).

8. REFERENCES

Bonner, N. (2004). *Seals and Seal Lions of the World.* Facts on File Inc., UK. ISBN-0816057176, 224pp.

Dietz, R., Teilmann, J., Henriksen, O.D. & Laidre, K. (2003). Movements of seals from Rødsand seal sanctuary monitored by satellite telemetry: relative importance of the Nysted Offshore Wind Farm area to the seals. NERI Technical Report No. 429.

Edrén, S.M.C., Teilmann, J., Dietz, R., Cartensen, J. (2004). Effect from the construction of Nysted offshore wind farm on seals in Rødsand Seal Sancturary based on remote video monitoring. Technical report to Energi E2 A/S. Ministry of the Environment, Denmark.

Edwards, B., Parvin, S.J., Nedwell, J.R. Workman, R., & Bourke, P.J. (2005). Subsea operational noise assessment at the Scroby Sands wind farm site. Subacoustech Report No. 655R0106.

Harwood, J. (2001). *The potential impact of a wind farm development on Scroby Sands, Norfolk, for grey and common seals. Report to Econet Ltd.*

Hewer, H.R. (1974). *British Seals.* William Collins Sons & Co Ltd Glasgow.

Jansen, J.K., Bengstron, J.L., Boveng, P.L. & Dahle, S.P. (2003). Investigation of the potential disturbance of harbour seals by cruise ships in Disenchantment Bay, Alaska, May-August

2002. Draft Report No. 1: field activities and preliminary results. Submitted fo the National Marine Mammal Laboratory, Alaska Fisheries Science Centre.

Lawton, N (2005). Scolt Head NNR. In: *Little Terns in Britain and Ireland, 2004* (ed. S. Scmitt). RSPB Conservation Science Dept., The Lodge, Sandy, Beds., UK pp.10-11.

Nedwell, J., & Howell, D. (2004). A review of offshore wind farm related underwater noise sources. Report No. 544 R 0308 commissioned by COWRIE.

Norfolk and Norwich Naturalists' Society. Norfolk Bird and Mammal Reports (1869-2002). Norfolk and Norwich Naturalists Trust, and Norfolk Naturalists' Society.

Sundberg, J & Söderman, M. (2000) Windpower and grey seals: An impact assessment of potential effects by sea-based windpower plants in local seal populations. Report produced by Department of Animal Ecology, Uppsala University for Energimyndigheter.

Thompson, D., Lonergan, M., & Duck, C. (2005). Population dynamics of seals *Phoca vitulina* in England: monitoring growth and catastrophic declines. *Journal of Applied Ecology*, 42:638-648.

Thompson, D., Duck, C.D. & McConnell, B.J. (1998) Biology of seals of the North-East Atlantic in relation to seismic surveys. *Proceedings of the Seismic and Marine Mammals Workshop London, 23-25 June 1998.*

Thompson, P.M., Fedak, M.A., McConnell, B.J., and Nicholas, K.S. (1989). Seasonal and sec-related variation in the activity patterns of Common seals (*Phoca vitulina*). *Journal of Applied Ecology*, 26, 521-535.

Thompson, P.M., Tollit, D.J., Wood, D., Cope, H.M., Hammond, P.S., and Mackay, A. (1997). Estimating harbour seal abundance and status in an estuarine habitat in north-east Scotland. *Journal of Applied Ecology*, 34, 43-52.

Thompson, P.M., Van Parijs, S., Kovacs, K.M. (2001). Local declines in the abundance of harbour seals: implications for the designation and monitoring of protected areas. *Journal of Applied Ecology*, 39, 117-125.

Tougaard, J., Ebbesen, I., Tougaard, S., Jensen, T., and Teilmann, J. (2003). Satellite tracking of Harbour Seals on Horns Reef: Use of the Horns Reed wind farm area and the North Sea. Report to Techwise A/S March 2003.

Tougaard, S., & Tougaard, J. (2003). Use of the North Sea by Harbour Seal with special emphasis on the Horns Reef area: test of prototype GPS/GSM-transmitter on harbour seals in the Sealarium, Esbjerg.

Trilateral Seal Expert Group (2003). Sense and Sensibility in Evaluating Aerial Counts of Harbour Seals in the Wadden Sea. In: *Wadden Sea Newsletter 2003.*

Appendix I

Seal counts for Scroby taken from the historic literature

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	
1958 Oct	6-7	No records.	The 8 pups found on Scroby on 7 Dec were tagged by Prof Hewer from Imperial College.
29 Nov	100 (nr sandbank)		
7 Dec	4 pups, 1 bull, several cows in with common herd		
1959 7 June	No records	Breeding season described as 'very good'	
1960 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		
1961 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.). 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. 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.
14 July	18	2 herds; 150 adults in total with 16 pups (most under 1 wk old, 2 later found dead)	
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		
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. Some of these were already in moult.
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		
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 27 Dec	Bred Horsey-Winterton: 30 pups (1 dead), 23 cows (inc 8 non-breeders), 12 bulls *(pers obs)*	Max count 67 pups (July)	
5 Jan	12 pups, 14 cows (inc. 8 non-breeders), 7 bulls *(pers obs)*		
2003 6 Dec 26 Dec	Bred Horsey-Winterton: Cows: 48, Pups: 51, Bulls: 14. Total: 113 (*Pers obs)* Cows: 23, Pups 32 Bulls 28, Total 82 (*pers obs)*	Max count 42 pups (August)	
2004 28 Nov	Bred Horsey-Winterton Cows: 50, Pups: 34, Bulls: 22. Total: 106.		3 Commons also observed. 14 people also on beach. Only 7 seals in top half of beach.
2004 26 Dec	Bred Horsey-Winterton Cows: 42, , Pups 33, Bulls: 37	Max count 16 (August)	107 people and 23 dogs also on beach. Of the 33 pups present only 17 were with their mothers – many had been separated.
2005 4 Dec	Horsey-Wint: Cows: 53, Bulls: 25, Pups: 39, Total: 117 (Commons: 7)		Near the entrance there were more people (23) taking photos and approaching seals very closely. Several pups on own. People pushing seals towards water, some cows displaced into water leaving pups behind, close enough to water to be partially submerged (embarrassingly the people photographing this pup were EN staff leading a group of National Trust members). One pup already shedding its languno coat, one pup dead (cause unclear), two cow & bull couples observed mating.