Farr windfarm: A review of displacement disturbance on golden plover arising from operational turbines between 2005-2009.

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Summary

1. Operational and construction impacts of the 40 turbine Farr windfarm on breeding golden plover were assessed over the period 2005 (pre-construction) to 2009 (operational).

2. Three hypotheses were tested: 1. No impact; 2. Immediate and permanent displacement of golden plover away from turbines; 3. Gradual but permanent displacement of golden plover away from turbines.

3. Golden plover territories were assigned to a 'windfarm' group if the territory centre was within a 500 m buffer drawn around the turbines. All others were assigned to a 'control' group.

4. Data on territory centres and nest locations (when available) were analysed using first and second order spatial statistics.

5. There was no evidence from either the first or second order spatial statistics to support Hypothesis 2 or 3. There were no systematic or significant shifts in the mean centres of golden plover territory centres or any changes in the variability of territory coordinates.

6. There was no evidence that territory centres moved away from turbine locations. This was true for both the nearest turbine and the average (mean or median distance) for the five nearest turbines.

7. During each survey approximately 40% of territory centres were less than 200 m from the nearest turbine, with no systematic trend apparent.

8. There was no evidence for a change in either the number or density (number per km^2) of turbines in the territory Thiessen polygons.

9. If hypothesis 2 was valid, and applying a 200 m displacement distance suggested by Pearce-Higgins *et al* (2009b), the area, within the windfarm, available for golden plover would have halved with a pro-rata reduction in the number of breeding golden plover. It is very clear from territory and nest locations that this has not happened at Farr.

10. The median distance from all 16 nests found to the nearest turbine was 168.8 m, with nine nests being less than 200 m and three less than 100 m from the nearest turbine.

11. There has been no decline in the proportion of territory centres that are less than 200 m from a turbine (range 37% – 48% between 2005 and 2009). There is no evidence that the centres of the territories have moved.

12. The number of turbines in a territory Thiessen polygon has remained relatively constant irrespective if it was measured as a count or a turbine density.

13. In conclusion, there is no evidence for an immediate, or even delayed, displacement away from turbines. There is also no evidence for a systematic change in the pattern of golden plover territories.

14. There is also no evidence to support the predicted 200 m displacement distance for golden plover reported in Pearce-Higgins *et al* (2009b).
15. Although there is uncertainty about the survival rates of adult golden plover needed to assess hypothesis 3 there is no evidence of a gradual decline predicted by this hypothesis.
16. Using figures suggested by RSPB (2007), in connection with the proposed Lewis windfarm, the Farr windfarm population is expected to have declined from 24 to 11 pairs by 2009. This has not happened.
17. The evidence presented against Hypothesis 2 is relevant to Hypothesis 3. In 2009, the fourth year of breeding with turbines present, there was no evidence for a change in the overall locations of golden plover territory centres and no evidence for an avoidance of any of the turbines.
18. **In conclusion, there is currently no evidence for a biologically significant decline in the number of golden plover breeding attempts at the Farr wind farm or in the spatial pattern of territories either with respect to each other or the turbines. Using current evidence the most parsimonious explanation of the observed results is scenario 1 – no biologically significant impact**.
19. Finally, we highlight the need for the publication of monitoring data from all operational wind farms so that the true level of their impacts on wildlife can be assessed.

20. Contents

1. Background

1.1 Farr Wind Farm was granted consent on the 5th October 2004 and construction began in April 2005. The last of 40 turbines was erected in March 2006, in advance of the 2006 golden plover breeding season. The consent had a number of conditions, including a requirement to undertake a breeding birds monitoring programme from the consent date (annually for three years from commissioning and subsequently at five year intervals, at 5, 10 and 15 years after the construction phase). This report deals with an analysis of the operational impacts on the distribution and abundance of golden plovers between 2005 and 2009.

1.2 The following analyses are predicated on three possible responses by golden plover to the windfarm construction and operation. Any impact is judged in comparisons between data from the control sites and within the windfarm.

1. **No biologically significant impact**: under this scenario some minor annual variation in the number and distribution of golden plover territories is expected but no significant systematic impacts, related to the windfarm, would be apparent.
2. **Immediate and permanent displacement**: under this scenario it is expected that, immediately after construction, there would be a displacement of birds away from turbines, in the wind farm area, leading to a change in the spatial distribution of territories and a permanent reduction in the number of territories. The size of this reduction would be determined by the magnitude of the displacement distance. Following this impact there will still be some minor annual variation in the number and distribution of golden plover territories.
3. **Gradual and permanent displacement**: under this scenario it is expected that there would no immediate or large displacement of birds away from turbines but that displacement effects would accumulate over time if birds are site-faithful or habituated. As Ratcliffe (1976) noted, there are indications that individual pairs returning in successive years tend to nest closer to the site of the previous year than do new birds. Consequently, as the original occupants die, under this scenario, they would not be replaced within the displacement zone and after a few years, the distribution and abundance would resemble scenario two.

1.3 Evidence in favour or against these three scenarios has been obtained by analysing the distribution and abundance of both golden plover territory centres and their nest sites (when available) in 2005, 2006, 2007, 2008 and 2009.

2. Data

2.1 Data on locations of golden plover territories and nest sites were extracted from Farr Breeding Wader reports (Ecology UK, 2005, 2008ab, 2009). In the 2006, 2007 report (Ecology UK, 2008a, sections 4.1.1.2 and 4.1.13) golden plover territory data from 2005 were re-assessed. Our analyses use the revised data from Table 5.5 in that report. Golden plover locations were derived indirectly from a cluster analysis of Brown and Shepherd (1993) registrations from three visits (four in 2009). Details of the methodology (e.g. distance measure and clustering algorithm) are not given in the reports. However, as RSPB (2007) noted in their response to the proposed Lewis Wind Farm, the Brown and Shepherd (1993) survey method was developed to survey large upland sites in order to establish population levels and trends and the method does not provide detailed information on territorial areas. Additionally, Pearce-Higgins and Yalden (2005) have suggested that Brown and Shepherd counts are likely to be an underestimate of the true population although Calladine *et al* (2009) suggested that robust population estimates could be derived from three survey visits for golden plover. Nonetheless, it is recognised that territory centres, derived from Brown and Shepherd surveys, can only be indicative and are subject to an undetermined positional error.

2.2 The locations of actual nest sites are given in the reports for 2005 and 2006 (Ecology UK, 2005, 2008a). Nests were located in these two years because a significantly increased survey effort was required to locate nest sites within the wind farm construction site and to feed this into the project management programme to avoid construction impacts on breeding birds (R. Frith *pers comm.*). Additionally, one nest location was identified in 2008 and 2009. In 2005 eight nests from an assumed 32 territories (25%) were located. In 2006 the percentage increased to 33% (14 nests from 43 territories). Because of the problems with golden plover nest mapping, and the absence of comparative data from recent years, we do not feel it appropriate to use nest location data to directly assess impacts. Consequently, only the estimated territory centres are used for most of our analyses. However, nest locations do provide more robust information about displacement distances.

2.3 Golden plover pair 9, in 2007, appears to have an incorrect y coordinate (Table 2, Ecology UK, 2008a). It has been assumed that the y coordinate should 312 and not 412. Using 412 makes this pair an extreme outlier and 312 is consistent with the mapped positions in Figure 6.4 of the same report.

2.4 There are some pre-construction data (2002-2004) that have not been used in our analyses. This is because the survey boundaries and methodology were not consistent with later surveys. However, there appear to have been considerably fewer golden plover territory centres within the area covered by the 500 m turbine buffer. The numbers were 10 (2002), 13 (2003) and 16 (2004) compared with a range from 20-27 between 2005 and 2009.

3. Methods

3.1 Golden plover territories were split into control and windfarm groups depending on the distance between the territory centre and the nearest turbine. Any centre greater than 500 m from the nearest turbine was assigned to the control group. This split is justified by:

a) the common use of a 500 m buffer to assess turbine impacts;
b) Brown and Shepherd (1993) suggest a minimum 1000m inter-territory distances (mid point of 500 m). However, it should be noted that, at Farr, nests were found much closer than this.
c) Pearce-Higgins *et al* (2009) suggest that golden plovers might be displaced by up to 200m.
d) Ratcliffe (1976), in his Table V, lists nest spacing distances of 420-430m

3.2 A variety of first and second order spatial statistics were used to describe patterns in golden plover territory centres and nest locations and to provide evidence for the magnitude of any disturbance or displacement effects. Statistics were calculated for all sites and, separately, for the wind farm and control sites. The majority of these analyses used Crimestat III (Levine, 2004).

3.3 Territory centre first order statistics

a) Minimum and maximum X and Y values.
b) Mean and median centre (arithmetic mean and median of the x and y coordinates).
c) Geometric and harmonic means of the X and Y coordinates.
d) Standard distance deviation (standard deviation of the distance of each point from the mean centre).
e) Centre of minimum distance (the point at which the distance to all other points is at a minimum).
f) Mean angle to the origin (defined by the minimum x and y coordinates).
g) Circular variance of the angles to the origin (range is 0 (none) to 1 (maximum).

3.4 Territory centre second order statistics

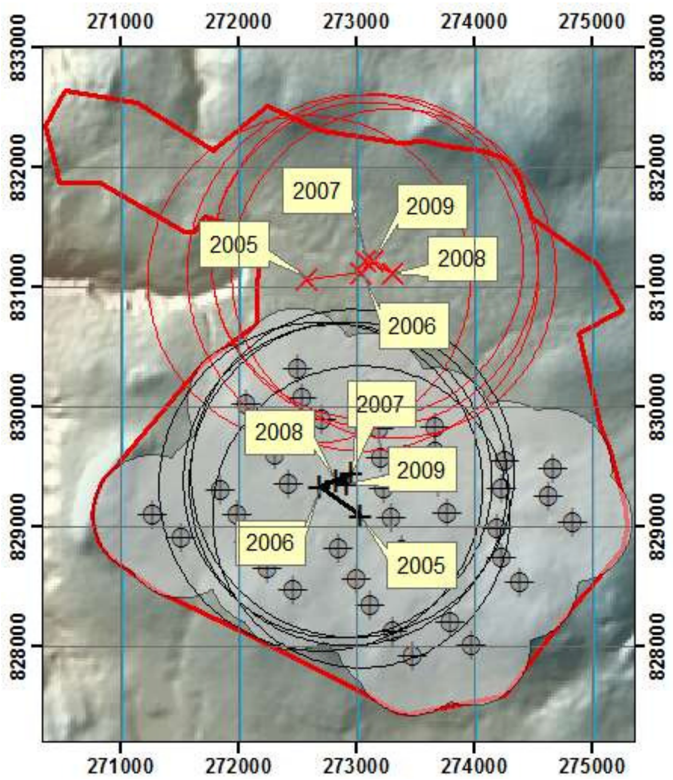
a) Nearest neighbour distance (distance to nearest golden plover territory centre). Note that this distance calculation precludes neighbours outside of the surveyed area but does include control territories when assessing wind farm territories and *vice versa*.
b) Distance to the nearest turbine (minimum and maximum distances, mean distance, standard error of the distance, first quartile, median (second quartile) and third quartile. Distances were also calculated for the second, third fourth and fifth nearest turbines.
c) Area of a territory defined by a Thiessen polygon with a maximum radius of 500 m. (A maximum radius is needed to take account of unsurveyed regions and natural territory boundaries in the absence of neighbours. The area within a Thiessen polygon is closer to the point on which the polygon is centred than it is to any other point in the dataset.
d) Number of turbines within a territory Thiessen polygon (wind farm group only).

4. Results

4.1 Detailed results are presented in Appendix 1.

4.2 There is no evidence from either the first or second order spatial statistics to support Scenario 2 or 3. For example, there have been no systematic or significant shifts in the mean centres of golden plover territory centres (Fig. 1) or any changes in the variability of territory coordinates (standard distance deviations). Similar results were obtained for control and wind farm territories.

Figure 1. Mean x and y coordinates for wind farm (+) and control (X) golden plover territories plus standard distance deviation circles for 2005-2009. Turbines are marked by a circle with a cross and the turbine 500 m buffer is shaded grey.



4.3 There is also no evidence that territory centres have moved away from turbine locations (Table A.1). This is true for both the nearest turbine and the average (mean or median distance) for the five nearest turbines (Table A.2 Appendix 1 and Figs 2a and 2b). During each survey approximately 40% of territory centres were less than 200 m from the nearest turbine, with no systematic trend apparent (Table 1).

4.4 There is no evidence for a change in either the number or density (number per km^2) of turbines in the territory Thiessen polygons (Table 2).

4.5 Figures 3 – 7 show the position of territory centres and their Thiessen polygons in relation to the turbine locations and turbine 500 m buffer. Also shown, when available, are the locations of nests.

Table 1. Number of golden plover territory centres less than 200 m from the nearest turbine.

Year	Territories	Less than 200 m n	%
2005	24	9	37.5
2006	27	11	40.7
2007	27	10	37.0
2008	27	13	48.1
2009	20	9	45.0

Table 2 Number of turbines, and turbine density, per territory Thiessen polygon.

	Turbines in Thiessen polygon								Turbines per km^2				
Year	**0**	**1**	**2**	**3**	**4**	**5**	**1+**	**(% 1+)**	**n**	**Mean**	**SE**	**Median**	**Max**
2005	3	10	6	5	0	0	21	87.5	24	4.1	0.57	3.7	8.4
2006	9	6	9	0	2	1	18	66.7	27	3.8	0.64	4.4	9.0
2007	8	7	8	3	1	0	19	70.4	27	3.6	0.60	3.4	10.3
2008	8	6	6	7	0	0	19	70.4	27	4.1	0.72	3.2	12.9
2009	3	6	6	4	0	1	17	85.0	20	3.8	0.52	4.0	8.6
All	31	35	35	19	3	2	94	75.2	125	3.9	0.28	3.6	12.9

Figure 2a and 2b. Mean (a) and median (b) distances from all (windfarm and control) golden plover territory centres to the nearest turbine and the average of the distances to the five nearest turbines.

a b

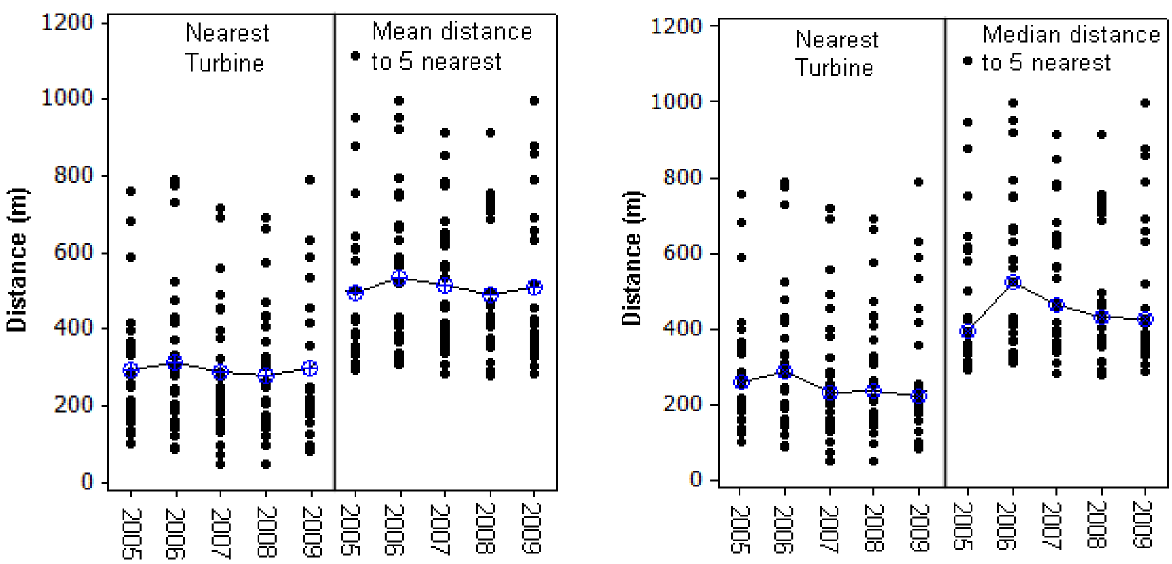


Figure 3. 2005 breeding season: Thiessen polygons, territory centres (+), nest sites (*) plus turbines and 500 m buffer and windfarm red line boundary. The grid is 1 km.

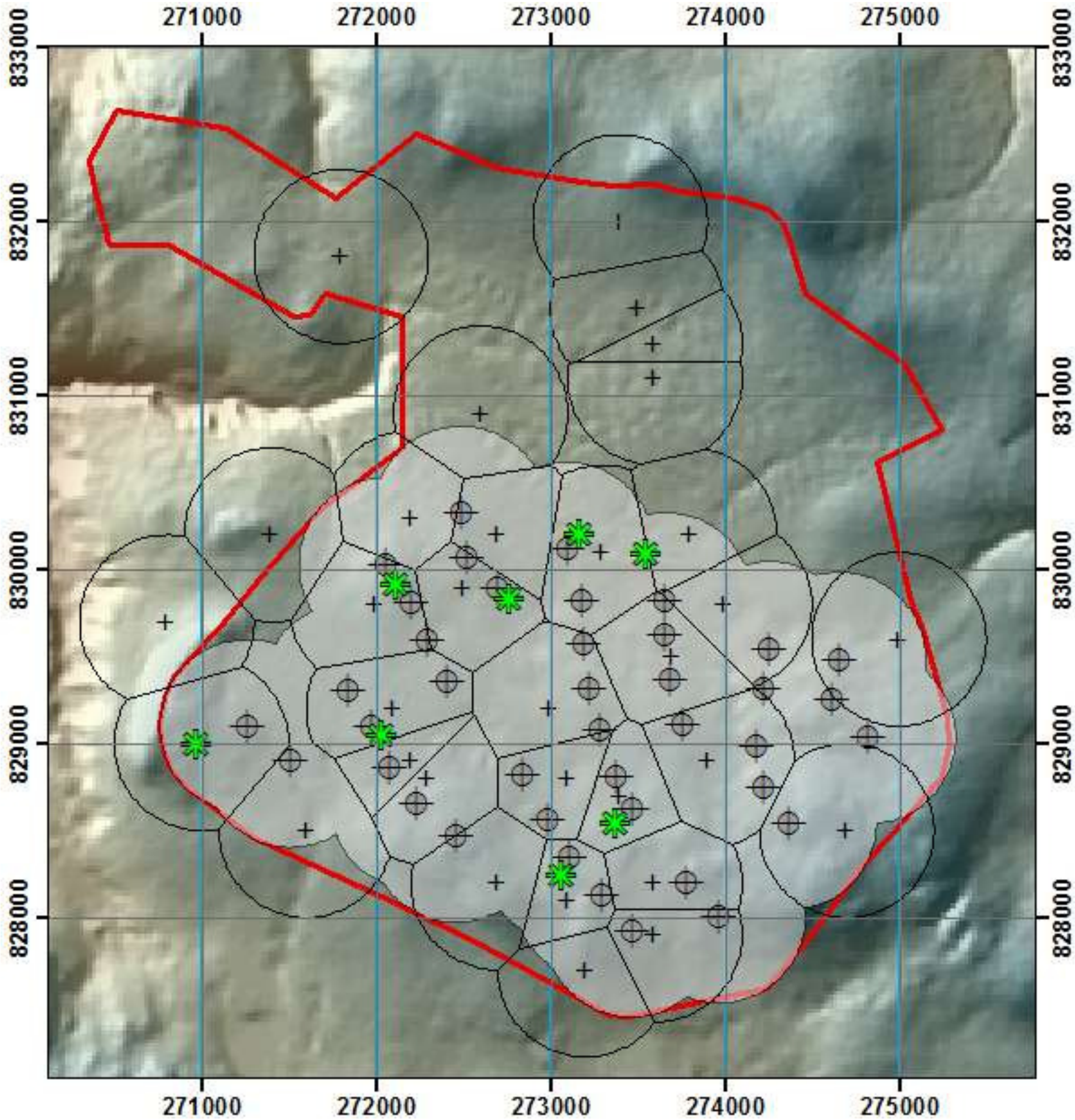


Figure 4. 2006 breeding season: Thiessen polygons, territory centres (+), nest sites (*) plus turbines and 500 m buffer and windfarm red line boundary. The grid is 1 km.

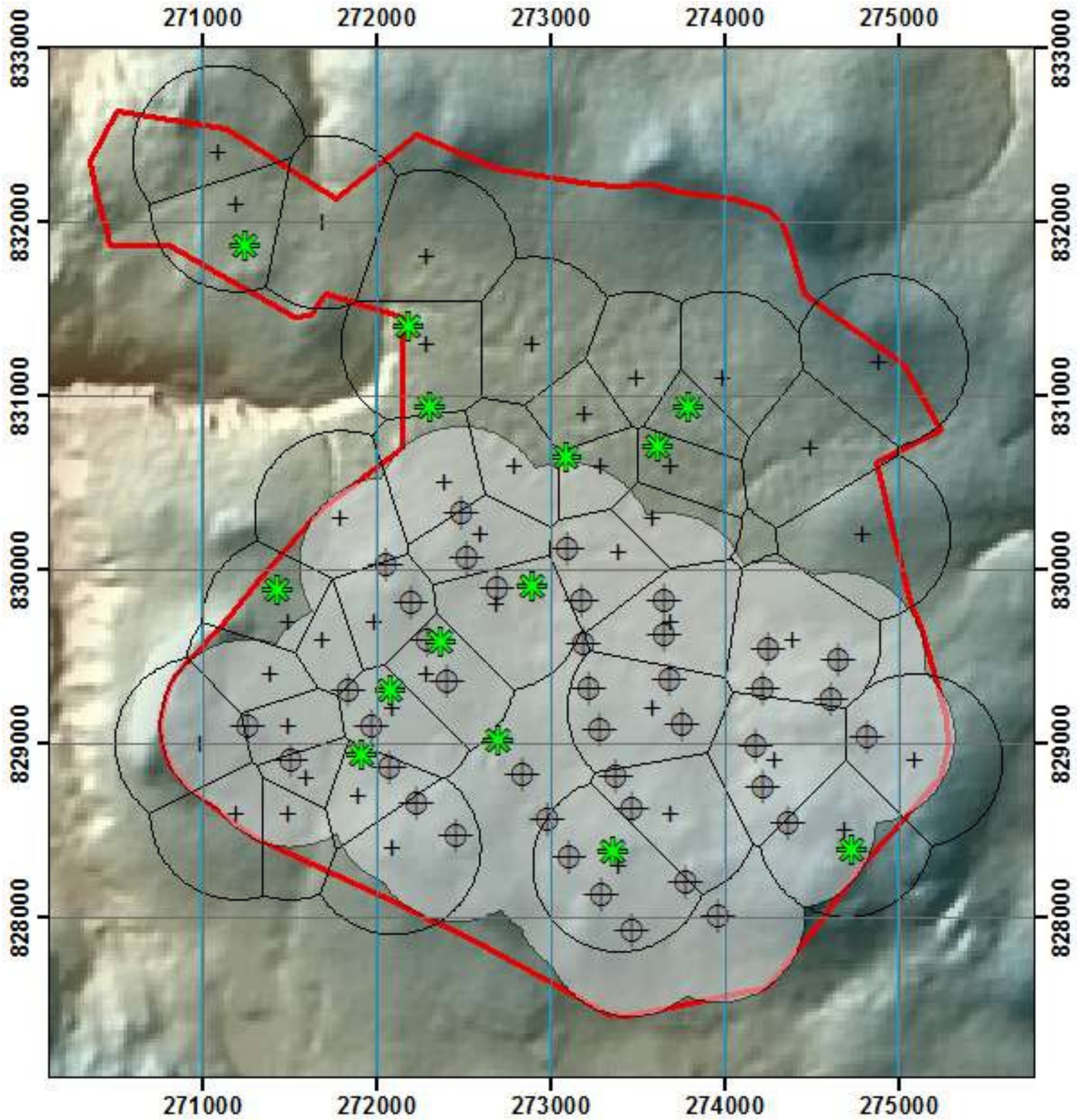


Figure 5. 2007 breeding season: Thiessen polygons, territory centres (+) plus turbines and 500 m buffer and windfarm red line boundary. The grid is 1 km.

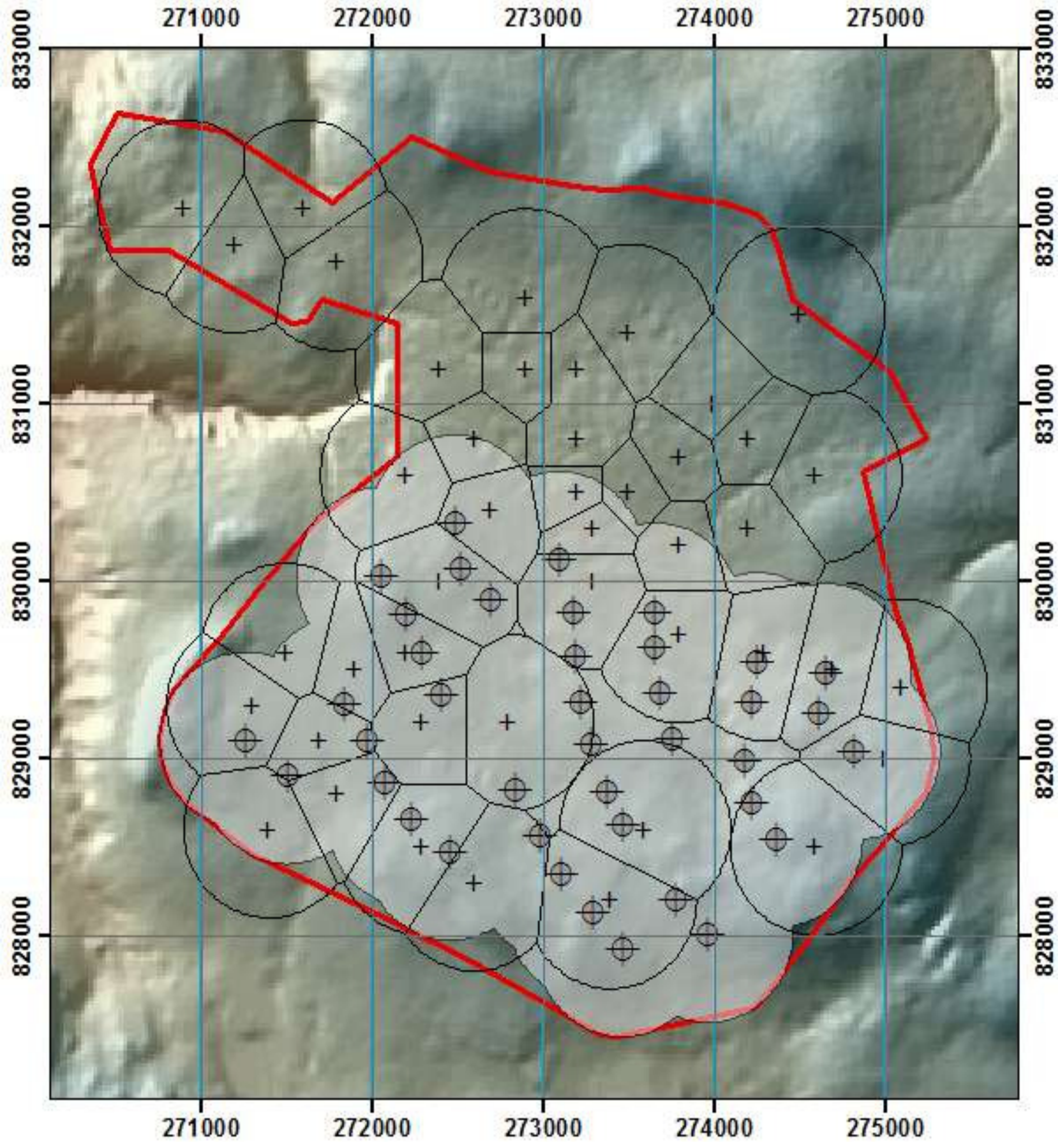


Figure 6. 2008 breeding season: Thiessen polygons, territory centres (+), nest sites (*) plus turbines and 500 m buffer and windfarm red line boundary. The grid is 1 km.

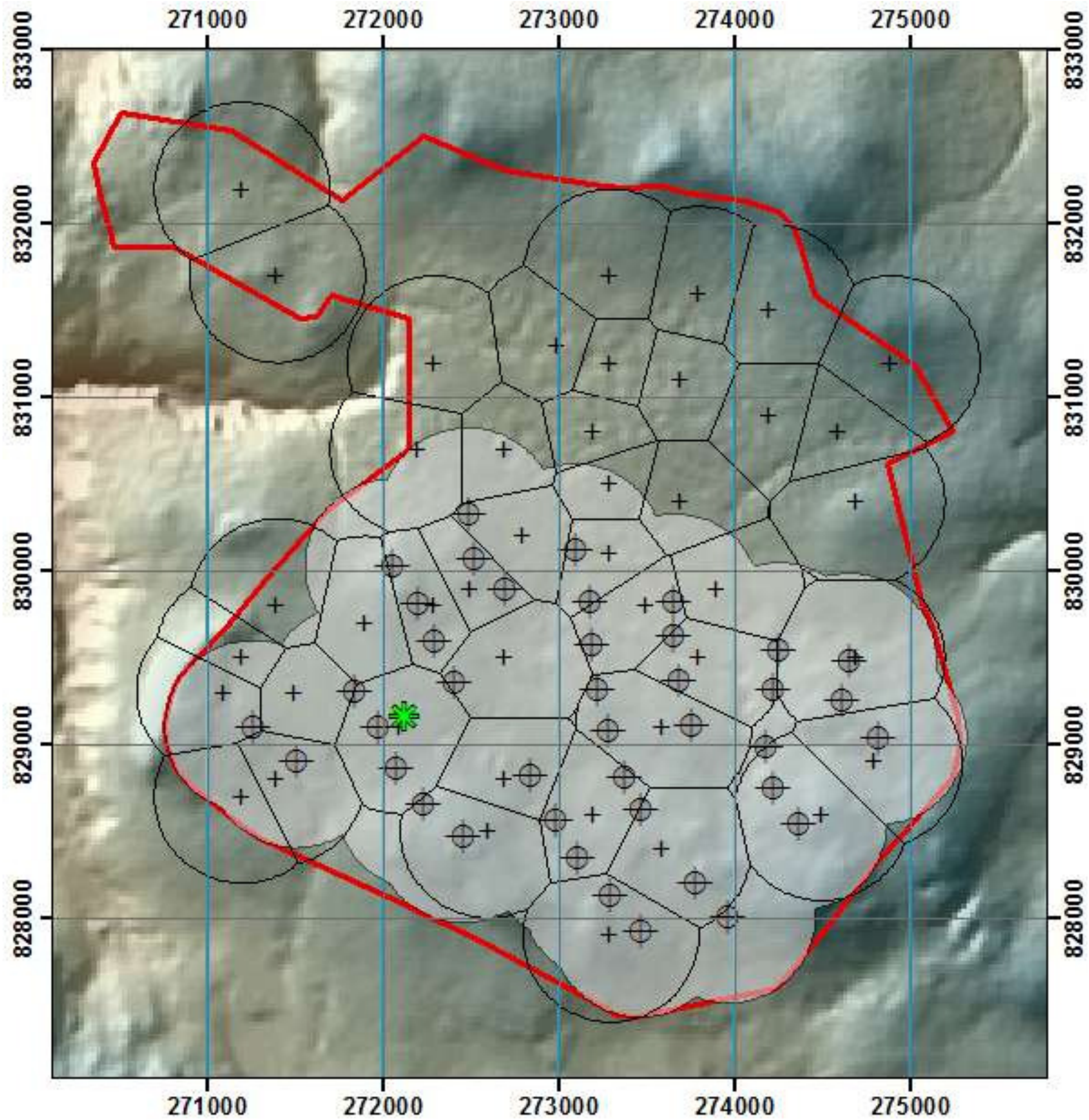
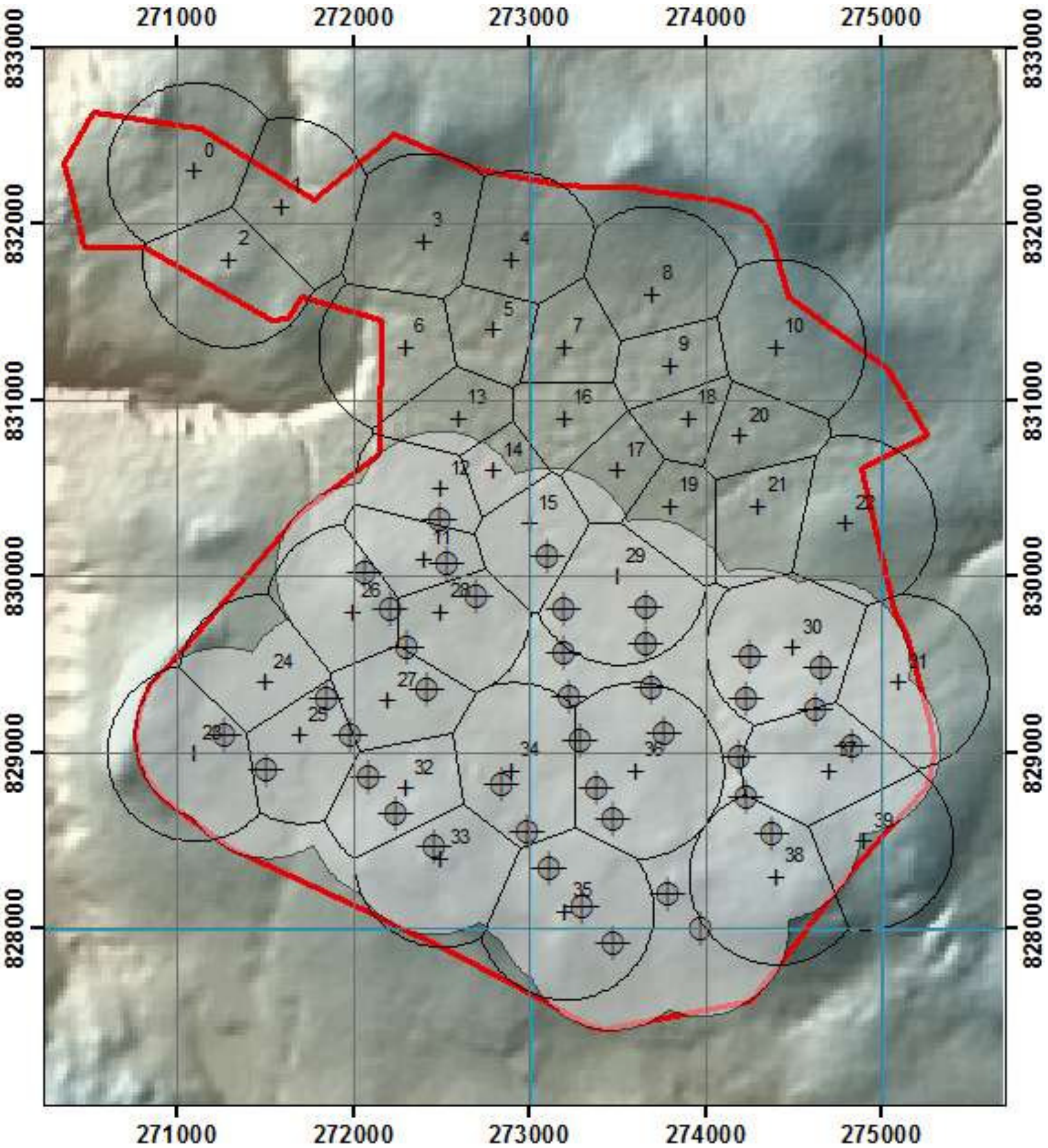


Figure 7. 2009 breeding season: Thiessen polygon and territory centres (+) plus turbines and 500 m buffer and windfarm red line boundary. The grid is 1 km.



5. Discussion

5.1 Scenario 2

5.1.1 Under this scenario there would be immediate displacement of golden plover away from the turbines. Pearce-Higgins *et al* (2009b) suggested a displacement distance of 200 m for this species. A 500 m buffer drawn around the turbines has an area of 962.3 ha while a 200 m buffer is 414.6 ha, leaving 57% of the wind farm between 200 and 500 m from a turbine. However, a more realistic figure is 50% since the layout of the turbines results in thin regions between turbine rows which would not be suitable for golden plovers if a 200 m exclusion zone applies. Consequently, 200 m displacement should result in an approximate 50% loss of habitat leading to a 50% reduction in the number of golden plover. It is very clear from Figures 3-7 and Tables A.1 and A.2 (Appendix 1) that this has not happened at Farr. Even if the territory centres are estimated inaccurately it is reasonable to assume that nest locations are recorded accurately. The median distance from all 16 nests found to the nearest turbine was 168.8 m, with nine nests being less than 200 m and three less than 100 m from the nearest turbine. Using derived territory centres there has been no decline in the proportion of territory centres that are less than 200 m from a turbine (range 37% – 48%, Table 1). There is no evidence that the centre of the territories has moved (Figure 1). It is possible to imagine a scenario in which the centre was unchanged but no golden plover occupied a central area within the windfarm. The Thiessen polygons and the range centres do not support that explanation because, if territories had been displaced away from the centre of the wind farm, there would have been an increase in the standard distance deviation circles. This has not happened. The number of turbines in a territory Thiessen polygon (Table 2) has remained relatively constant irrespective if it is measured as a count or a turbine density. In conclusion, there is no evidence for an immediate, or even delayed, displacement away from turbines. There is also no evidence for a systematic change in the pattern of golden plover territories. There is also no evidence to support the predicted 200 m displacement distance for golden plover reported in Pearce-Higgins *et al* (2009b).

5.2 Scenario 3

Expected rate of decline

5.2.1 Under this scenario an annual decline in the number of golden plovers is expected in the wind farm region at a rate that is a function of the annual adult survival rate. Unfortunately, given the range of values quoted by the EU (2006), estimates of golden plover vital rates appear imprecise. Few studies have been carried out on the demography of the species and the range of quoted values is quite large (e.g. 0.61 to 0.88 for the annual survival of adult birds). Additionally, survival rates appear to be affected by winter severity (e.g. Parr 1992 and Yalden and Pearce-Higgins 1997). Indeed, golden plover appear to be quite sensitive to weather conditions with Pearce-Higgins *et al* (2005) providing evidence for a link between spring weather and breeding phenology and, more recently, Pearce-Higgins *et al* (2009a) found a significant negative relationship with the August temperatures two years previously (via an impact on cranefly abundance). In the RSPB (2007) response to the proposed Lewis Wind Farm, it was suggested that vital rates could be used for population modelling that were based on Parr (1980) and Pearce-Higgins and Yalden (2003). The suggested values were 0.57 fledglings per pair per year, a 0.59 first-year annual survival rate and a 0.834 adult survival rate. If these values are used in a female-only population model (reproductive rate = 0.285, assuming an equal sex ratio) the predicted growth rate is 1.0086 (effectively a stable population).

5.2.2 Table 3 shows the estimated number of pairs within the windfarm under Scenarios 1 (no impact) and Scenario 3 (gradual loss through a lack of recruitment). An annual adult survival rate of 0.834 implies an annual adult mortality rate of 0.166. If adults were lost from an initial wind farm population of 24 pairs at this rate, with no replacement, the number of pairs within the wind farm would be reduced to 11 pairs by 2009. The survey data does not provide evidence for such a decline. There were 27 pairs within the wind farm between 2006 and 2008 with 20 pairs in 2009. This amount of decline, if it is real and not a sampling or methodological artefact, is well within the range described by Jenkins and Watson (2001) for a similar sized population of golden plover and that shown in Figure 5 of Pearce-Higgins *et al* (2009a) for the period 1972-2005 (11 to more than 40).

5.2.3 Because golden plover populations appear to exhibit some instability, partly in response to winter weather conditions, it may be difficult to separate out wind farm impact effects from population dynamics 'noise'. For example, Sim *et al* (2005) showed that there was no change in the abundance of Golden Plover in a small area of Moray between 1988/89 and 1997, while they declined sharply between 1987 and 1994 in NW and mid-Wales. There was also evidence for longer-term national range decline between 1968–72 and 1988–89. Similarly, Jenkins and Watson (2001), in a more focused study, recorded populations between 25 and 32 pairs between 1958 and 1961 on a grouse moor in NE Scotland.

5.2.4 If it is true that golden plover survival rates are affected by winter severity (e.g. Parr 1992 and Yalden and Pearce-Higgins 1997) it is possible, given the weather between December 2009 and February 2010, that there may be a significant reduction in occupancy in spring 2010.

Table 3. Estimated numbers of golden plover pairs within the wind farm expected under impact scenarios 1 and 3. The rate of decline assumes an annual mortality rate of 16.6% with no replacement. Under scenario 3 the annual survival rates are 83.4% for adults, 59.0% for first year birds and 0.57 young fledged per territorial pair. 'Surviving' is the number of young predicted to survive year one and then return to the population

	Scenario 3 Without recruitment			Scenario 1 With recruitment			
Year	**Individuals**	**% decline**	**Pairs**	**Young**	**Surviving**	**Individuals**	**Pairs**
2005	48		24	13.7	8	48	24
2006	39.9	83	19	13.1	7	48	24
2007	33.2	69	16	13.1	7	47	23
2008	27.6	58	13	13.1	7	47	23
2009	23.0	48	11	13.1	7	46	23
2010	19.1	40	9	13.1	7	46	23
2011	15.9	33	7	12.5	7	46	22
2012	13.2	28	6	12.5	7	45	22
2013	11.0	23	5	12.5	7	45	22
2014	9.2	19	4	12.5	7	44	22
2015	7.6	16	3	12.5	7	44	22

6. Conclusions

6.1 Hypothesis 2 can be rejected since there is no evidence of an immediate change in golden plover distribution or abundance following the construction of the turbines prior to the 2006 breeding season. Although the territory centre data is strong evidence against this hypothesis the distribution of golden plover nests in 2005 and 2006 is conclusive proof of no immediate and significant displacement away from turbines.

6.2 The remaining hypotheses 1 and 3 can be separated if there is robust evidence of a decline in the number of golden plover following construction of the windfarm in advance of the 2006 breeding season. Between 2006 and 2009 there was no evidence for the predicted population decline within the wind farm. Even the apparent decline in 2009 is much smaller than that predicted by a habituation-philopatry hypothesis and the reduction is consistent with observed variation in local populations (e.g. Jenkins and Watson, 2001). Also, the evidence presented against Scenario 2 is relevant. In 2009, the fourth year of breeding with turbines present, there was no evidence for a change in the overall locations of golden plover territory centres and no evidence for an avoidance of turbines.

6.3 It is clear that the estimated number of occupied territories should be treated cautiously, particularly when the apparent reduction in 2009 coincided with changes in the surveying methodology. It is also clear that the reduction in the 2009 golden plover wind farm population was not consistent with a local displacement around turbines. The distances between turbines and territory centres (Figs 2a and 2b) did not increase significantly. However, a continued reduction in the wind farm population in subsequent years would be stronger evidence for an impact, particularly if the control population remains unchanged.

6.4 In conclusion, there is currently no evidence for a biologically significant decline in the number of golden plover breeding attempts at the Farr wind farm or in the spatial pattern of territories either with respect to each other or the turbines. Using current evidence the most parsimonious explanation of the observed results is scenario 1 – no biologically significant impact.

7. Postscript

7.1 The main conclusion of this report is that there is no evidence for a displacement effect of the Farr wind farm on golden plover. This is consistent with the apparent absence of significant reported actual, rather than predicted, impacts of wind farms on any birds in the United Kingdom. This raises an important question. Is the absence of any significant effects real or it is an artefact of under-recording and non-reporting? It is difficult to separate out these two hypotheses because it is surprisingly difficult to obtain monitoring data from operational onshore wind farms in the United Kingdom. Presumably the shortage of monitoring information is either because monitoring has not been undertaken or it has not been reported. It is very important, for both conservation agencies and the wind energy industries, that the true level of wind farm impacts on birds, and other wildlife, is fully documented and assessed. Only then will it be possible to undertake meaningful cumulative impact assessments. These assessments are only possible when wind farms are monitored and reported.

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Appendix 1 Spatial Statistics

A.1. Territory average centres

All territories		Minimum		Maximum		Simple		Geometric		Harmonic		Median	
Year	n	x	y	x	y	x	y	x	y	x	y	x	y
2005	32	270800	827700	275000	832000	272919	829578	272917	829577	272915	829577	273100	829550
2006	43	271000	828300	275100	832400	272819	829998	272816	829997	272814	829996	272700	829800
2007	44	270900	828200	275100	832100	273005	830130	273002	830129	273000	830128	273050	830250
2008	43	271100	827900	274900	832200	273007	830026	273005	830025	273003	830024	273200	829900
2009	40	271100	828100	275100	832300	273078	830223	273075	830222	273073	830221	272950	830350
Min	32	270800	827700	274900	832000	272819	829578	272816	829577	272814	829577	272700	829550
Max	44	271100	828300	275100	832400	273078	830223	273075	830222	273073	830221	273200	830350
Control Territories													
2005	8	270800	829700	273600	832000	272588	831063	272585	831062	272583	831062	273000	831200
2006	16	271100	829700	274900	832400	273043	831119	273041	831118	273038	831118	273250	831100
2007	17	270900	830300	274600	832100	273082	831218	273080	831217	273077	831217	273200	831200
2008	16	271200	829800	274900	832200	273306	831113	273303	831112	273301	31112	273500	831200
2009	20	271100	830300	274800	832300	273147	831221	273145	831221	273143	831221	273200	831300
Min	16	270800	829700	273600	832000	272588	831063	272585	831062	272583	31112	273000	831100
Max	19	271200	830300	274900	832400	273306	831221	273303	831221	273301	831221	273500	831300
Wind farm territories													
2005	24	271000	827700	275000	830300	273029	829083	273028	829083	273026	829083	273100	828950
2006	27	271000	828300	275100	830600	272685	829333	272683	829333	272680	829333	272400	829200
2007	27	271300	828200	275100	830800	272956	829444	272953	829444	272951	829444	272700	829500
2008	27	271100	827900	274800	830700	272830	829381	272828	829381	272826	829381	272700	829500
2009	20	271100	828100	275100	830600	272920	829360	272918	829360	272916	829359	272650	829350
Min	20	271000	827700	274800	830300	272685	829083	272683	829083	272680	829083	272400	828950
Max	27	271300	828300	275100	830800	273029	829444	273028	829444	273026	829444	273100	829500

All territories		Centre of minimum distance (X Y)		Mean angle		Circular variance	
Year	n	x	y	raw	weighted	raw	weighted
2005	32	272916	829459	48.7	48.4	0.07765	0.06995
2006	43	272795	830037	45.9	47.0	0.07938	0.08067
2007	44	273132	830262	47.9	47.5	0.06825	0.06977
2008	43	273058	830080	40.4	41.9	0.07451	0.06334
2009	40	273057	830348	43.0	43.0	0.08025	0.07676
Min	32	272795	829459	40.4	41.9	0.06825	0.06334
Max	44	273132	830348	48.7	48.4	0.08025	0.08067
Control Territories							
2005	8	272978	831216	51.6	52.7	0.0205	0.0197
2006	16	273277	830988	53.0	53.9	0.1046	0.0955
2007	17	273203	831191	61.8	67.2	0.1057	0.0841
2008	16	273471	831144	57.0	58.1	0.0814	0.0651
2009	20	273238	831192	61.1	65.7	0.1012	0.0871
Min	16	272978	830988	51.6	52.7	0.0205	0.0197
Max	19	273471	831216	61.8	67.2	0.1057	0.0955
Wind farm territories							
2005	24	273028	829045	54.0	55.7	0.06926	0.05859
2006	27	272383	829396	52.7	58.5	0.07840	0.07041
2007	27	272793	829485	48.0	53.1	0.09253	0.07876
2008	27	272728	829486	45.0	49.4	0.08835	0.07367
2009	20	272703	829428	50.9	55.3	0.08610	0.07317
Min	20	272383	829045	45.0	49.4	0.06926	0.05859
Max	27	273028	829486	54.0	58.5	0.09253	0.07876

A.2. Distances (mean, standard error, first quartile, median, 3rd quartile, minimum, maximum and sample size) from wind farm nest sites to the nearest three turbines (m)

		Mean	SE	Q1	Median	Q3	Min	Max	n
Nearest turbine									
	2005	157.2	30.8	101.6	121.0	248.7	83.4	304.4	8
	2006	227.2	37.4	172.6	232.5	255.2	77.4	406.5	7
	2008	165.0							1
All years		188.3	23.4	114.3	168.8	250.8	77.4	406.5	16
Second nearest turbine									
	2005	321.9	49.0	202.6	305.2	444.8	132.5	539.1	8
	2006	325.1	60.7	226.7	258.5	450.1	176.6	632.6	7
	2008	296.7							1
All years		321.7	34.8	230.2	277.3	435.1	132.5	632.6	16
Third nearest turbine									
	2005	464.8	72.1	327.2	388.8	547.4	324.8	921.9	8
	2006	394.7	55.5	286.2	333.9	538.8	269.0	655.1	7
	2008	323.9							1
All years		425.3	43.3	324.1	348.2	520	269	921.9	16
Mean of 1st, 2nd and 3rd distances									
	2005	314.7	47.0	213.8	262.3	394.2	198.4	588.5	8
	2006	315.7	48.2	243.8	265.3	408.9	196.8	564.8	7
	2008	261.8							1
All years		311.8	30.6	232.6	263.6	394.2	196.8	588.5	16

A.3. Areas (ha) of Thiessen polygons constructed around golden plover territory centres (mean, standard error, 1st quartile, median, second quartile, minimum, maximum, sample size, upper and lower 95% confidence limits).

Year	Mean	SE	Q1	Median	Q3	Min	Max	n	LCL	UCL
All territories										
2005	46.6	3.1	33.3	44.5	64.6	17.4	78.5	32	40.4	52.8
2006	37.5	2.4	22.4	39.2	51.4	11.1	68.4	43	32.7	42.3
2007	36.7	2.4	20.8	39.1	47.7	11.6	69.7	44	31.9	41.5
2008	38.3	2.1	26.7	33.6	48.1	16.9	64.8	43	34.0	42.6
2009	40.9	2.4	24.6	41.1	52.0	14.9	69.9	40	35.9	45.8
All	39.6	1.1	26.0	39.6	51.0	11.1	78.5	202	37.4	41.8
Control										
2005	55.8	6.8	38.6	64.3	67.4	21.1	78.5	8	40.1	71.6
2006	40.0	4.1	23.0	43.1	52.9	14.6	68.4	16	31.3	48.7
2007	35.5	4.1	19.5	37.1	49.6	12.8	69.7	17	26.9	44.1
2008	40.6	3.9	28.1	37.9	55.9	16.9	64.8	16	32.4	48.9
2009	37.1	3.3	23.2	36.9	50.0	16.5	58.5	20	30.2	44.0
All	40.0	1.9	24.2	41.9	52.4	12.8	78.5	77	36.2	43.9
Windfarm										
2005	43.5	3.2	32.6	41.4	48.3	17.4	78.5	24	36.9	50.2
2006	36.0	2.9	22.4	32.7	48.9	11.1	64.3	27	29.9	42.0
2007	37.4	3.0	22.6	39.1	46.4	11.6	68.9	27	31.3	43.6
2008	36.9	2.6	26.4	33.5	46.7	18.1	63.6	27	31.7	42.2
2009	44.6	3.5	32.7	41.7	59.5	14.9	69.9	20	37.3	51.9
All	39.3	1.4	27.0	39.2	48.9	11.1	78.5	125	36.6	42.0