



# Summary

## Background

Wind energy is the fastest growing energy technology in the world, with a yearly growth rate estimated at 30%, reflecting policy commitments in many countries to renewable energy in order to meet greenhouse gas emission targets. Wind energy is seen as a key element of the shift to sustainable energy supplies; however, despite the clean image of wind energy, there is some evidence that wind farm developments may have potentially deleterious environmental impacts. Attention has been brought to the possible impacts on bird populations caused by displacement and direct 'bird strikes'. Here we systematically review the impact of wind turbines on bird population abundance.

## Objective

The objective has been to assess the evidence on the positive and negative effects of wind turbines on bird abundance. To achieve this four questions were identified:

1. Do wind turbines effect bird abundance?
2. Are some bird taxon more vulnerable than others?
3. Does the number or power of turbines in a windfarm installation have an impact on the effect of windfarms on bird abundance?
4. Can any other ecological factors or windfarm characteristics be identified which have an impact on the effect of windfarms on bird abundance?

## Study Inclusion Criteria

Studies were included if they fulfilled the relevance criteria below.

- *Subjects(s)* studied – any bird species (information was extracted on Falconiformes & Accipitriformes, Anseriformes, Passeriformes and Charadriiformes except *Laridae*).
- *Intervention* used – commercial wind installations in any country: wind farms and turbines.
- *Outcome(s)* – population size or distribution, breeding success, population mortality rate, recruitment rate, turnover rate, immigration rate, emigration rate, demography, dispersal behaviour, collision mortality, displacement disturbance, movement impeded, and habitat loss or damage. (Only information on bird abundance was extracted).
- *Comparator* – appropriate controls (e.g. reference areas) or pre-development comparators

- *Type of study* – any primary studies

### **Scope of the Search**

The following computerised databases were searched: English Nature's "Wildlink, JSTOR, Index to Theses Online (1970 to present), Internet search – Dogpile meta-search engine, SCIRUS, COPAC and ISI Web of Knowledge. In addition, the RSPB library was hand-searched, as were bibliographies. Recognised experts and current practitioners in the fields of applied avian ecology and renewable energy technology were contacted. Foreign language searches were undertaken to ensure that the scope of the review was truly global.

### **Main results**

A total of 124 articles were accepted for full text viewing based upon an initial screening of title and abstract, including foreign language articles. Of these, 15 were of sufficient quality and relevance to meet the inclusion criteria reporting on the results of 19 datasets. Nine of these datasets were complete although three only reported on a limited number species. The remaining 10 datasets were incomplete. Nine did not present variance measures, one did not include turbine characteristics and three of the sites were not independent as they shared the same control.

Random effects weighted mean difference meta-analysis of six complete independent datasets with more than three species produced negative effect sizes, two of which were statistically significant, suggesting that windfarms can have a negative impact on bird abundance. Combination of the complete datasets using Random effects standardised mean difference meta-analysis resulted in a pooled effect size of  $-0.328$  ( $P < 0.0001$ ). The inclusion of incomplete datasets (with down-weighted dummy variances) reduced the size of the effect and its significance ( $-0.033$ ,  $P = 0.002$ ), whilst including these data with average weighting further reduced the effect size and probability fell beyond the 0.05 significance threshold ( $-0.022$ ,  $P = 0.054$ ).

Combination of the complete datasets with effect sizes derived from overall means of within-windfarm samples resulted in a negative and significant pooled effect size ( $-0.712$ ,  $P = 0.0001$ ) which remained with the addition of down-weighted data with dummy variances and non-independent data. ( $-0.257$ ,  $P = 0.023$ ). Effect sizes were also derived using species as replicates and again the pooled effect size was negative and significant ( $-0.489$ ,  $P = 0.035$ ) although the significance fell beyond the 0.05 threshold when down-weighted data with dummy variances and non-independent data was added ( $-0.240$ ,  $P = 0.089$ ).

Meta-regression was used to investigate reasons for heterogeneity in results. Bird taxon had a significant impact on the effect of windfarms on bird abundance ( $r = 0.290$ ,  $SE = 0.070$ ,  $P = 0.0001$ ) with Anseriformes (ducks) experiencing greater declines in abundance than other bird groups, followed by Charadriiformes (waders), Falconiformes and Accipitriformes (raptors) and Passeriformes (songbirds).

Turbine number did not have a significant impact on bird abundance whilst turbine power had a very weak but statistically significant effect ( $r = 0.002$ ,  $SE = 0.0007$ ,  $P = 0.004$ ) with low power turbines resulting in greater declines in abundance than high

power turbines.

Bird taxon, turbine number and turbine power were combined with habitat type, the migratory nature of the species, latitude, location, size of area, time since operation of windfarm and data quality using multivariate meta-regression. Time since windfarms commenced operation had a significant impact on bird abundance ( $r = 0.519$ ,  $SE = 0.155$ ,  $P = 0.001$ ) with longer operating times resulting in greater declines in abundance than short operating times. Latitude had a very weak but statistically significant effect ( $r = -0.099$ ,  $SE = 0.032$ ,  $P = 0.002$ ) with high latitudes resulting in greater declines in abundance than low latitudes.

## Conclusions

*Available evidence suggests that windfarms reduce the abundance of many bird species at the windfarm site. There is some evidence that Anseriformes (ducks) experience greater declines in abundance than other bird groups suggesting that a precautionary approach should be adopted to windfarm developments near aggregations of Anseriformes and to a lesser extent Charadriiformes particularly in offshore and coastal locations. There is also some evidence that impact of windfarms on bird abundance becomes more pronounced with time, suggesting that short term bird abundance studies do not provide robust indicators of the potentially deleterious impacts of windfarms on bird abundance.*

*These results should be interpreted with caution given the small sample sizes and variable quality data. More high quality research and monitoring is required, in particular, long term studies with independent controls and variance data. Pending further research, if impacts on bird abundance are to be avoided, the available evidence suggests that windfarms should not be sited near populations of birds of conservation importance, particularly Anseriformes.*

## Background

The broad weight of current scientific opinion supports the view that anthropogenically caused climate change is a reality (United Nations Framework Convention on Climate Change 2005). To minimise gaseous emissions linked with climate change, the energy production industry is moving increasingly toward renewable sources. Wind energy is the fastest growing energy technology in the world, with a yearly growth rate estimated at 30%, reflecting policy commitments by many countries to renewable energy in order to meet greenhouse gas emission targets (BWEA 2004). Wind energy is seen as a key element of the shift to sustainable energy supplies in many western countries and is set to make a significant contribution to their generation capacity (BWEA 2004). The UK Government has set a target to generate 10% of the UK's electricity from renewable sources of energy by 2010. There are currently 1060 turbines in 83 wind energy installations, and many more with planning consent (BWEA 2004).

A typical wind farm of 20 turbines might extend over an area of 1 Km<sup>2</sup>. It is generally agreed that the ideal position for a wind turbine generator is a smooth hill top, with a flat clear fetch, at least in the prevailing wind direction (BWEA 2004). Wind farms are sited in exposed areas to ensure high average wind speeds to maximise energy capture, a requirement commonly but not exclusively met in coastal, upland and offshore areas. Such locations are often important and sensitive wildlife habitats, therefore wind energy developments have potentially deleterious environmental impacts on wildlife, including bird species. Attention has been brought to the possible impacts on bird populations caused by displacement and direct 'bird strikes' (Langston and Pullan 2003, Percival 2001, Gill, Townsley and Mudge 1996).

The main potential hazards to birds from wind farms are disturbance leading to displacement or exclusion from areas of suitable habitat, collision mortality and loss of, or damage to, habitat resulting from wind turbines and associated infrastructure Langston and Pullan (2003). The ultimate measure of these effects is change in the abundance of a species. Thus this review aims to assess the potential positive and negative impacts of wind farms on bird abundance.

The potential impact of windfarms on bird species depend on a number of factors. Variation in response from one species to another is an obvious source of potential heterogeneity. Raptors, breeding waders particularly in upland areas, swans, geese, coastal waders, common scoters *Melanitta nigra* at sea, and sea ducks in general were identified as of particular concern Langston and Pullan (2003). The review therefore considers taxon as a potential reason for heterogeneity in results. Likewise the number and power of turbines may affect the impact of windfarms on bird species along with other ecological and windfarm characteristics.

The explicit methods used in this systematic review limit bias through the use of comprehensive searching, specific inclusion criteria and formal assessment of the quality and reliability of the studies retrieved. The use of meta-analysis increases statistical power and thus the precision of estimates of treatment effects providing robust empirical evidence on the impact of windfarms on bird species. Meta-regression allows exploration of reasons for any heterogeneity in results providing

testable hypotheses about ecological or windfarm characteristics that may have an impact on the effect of windfarms on bird abundance. Finally, the review highlights gaps in research evidence identifying needs-led research as a priority for future funding.

## **Objective**

The objective is to assess the evidence on the positive and negative effects of wind turbines on bird abundance. To achieve this four questions were identified:

1. Do wind turbines effect bird abundance?
2. Are some bird taxon more vulnerable than others?
3. Does the number or power of turbines in a windfarm installation have an impact on the effect of windfarms on bird abundance?
4. Can any other ecological or windfarm characteristics be identified which have an impact on the effect of windfarms on bird abundance?

## **Methods**

### ***Question formulation***

Question formulation was an iterative process involving CEBC and RSPB personnel. Initially, the primary question was do wind turbines effect bird species? with secondary questions considering the modifying effects of ecological and windfarm characteristics. It was subsequently recognised that the substantial differences in the characteristics of the populations, interventions and types of outcome would have a large influence on the estimates of effect thus explaining apparent differences in the findings of primary studies. It is vital that these factors are specified *a priori*, and supported by a scientific rationale (Khan *et al.* 2000). Consequently, the objectives outlined above were developed prior to data extraction, with tighter definitions of outcome and ecological and windfarm characteristics. The outcome was restricted to bird abundance. Primary reasons for heterogeneity in results were: taxon, turbine number and turbine power (as a rough surrogate for size). Location (offshore, coastal, inland), latitude, habitat type, size of area (km<sup>2</sup>), time since start of windfarm operation (years), migratory status of the species and quality of evidence were defined as potential reasons for heterogeneity for exploratory analysis.

### ***Search strategy***

#### ***Electronic database and internet searches***

The databases searched were: English Nature's "Wildlink" database, JSTOR, Index to Theses Online (1970 to present), Internet search – Dogpile meta-search engine, SCIRUS, COPAC and ISI Web of Knowledge.

Search terms were as follows:

- bird\* AND wind turbine\*
- bird\* AND windfarm\*
- bird\* AND wind park\*
- bird\* AND wind AND turbine\*
- bird\* AND wind AND farm\*
- bird\* AND wind AND park\*
- bird\* AND wind AND installation\*
- raptor\* AND wind\*
- wader\* AND wind\*
- duck\* AND wind\*
- swan\* AND wind\*
- geese AND wind\*
- goose AND wind\*

Although the term “wind\*” encompasses the terms “wind turbine\*”, “windfarm\*” and “wind park\*”, initial trials proved that the number of hits become unmanageable when using this strategy in conjunction with the term “bird\*”, for example the JSTOR database limit of 2500 articles was exceeded. The increased specificity of these terms made data retrieval feasible.

The Dogpile meta-search engine was searched using the advanced search facility, and the terms “bird AND wind AND turbine”. It was also searched using the following foreign languages and terms: German “Vögel AND Windturbinen”, French “oiseaux AND turbines AND éoliennes”, Spanish “pájaros AND turbinas AND viento”, Dutch “vogels AND windturbinen”, Norwegian “fugle AND vindkraft”, Danish “fugle AND vindkraft”, Finnish “lintu AND vindkraft”, Swedish “fåglar AND vindkraft”, Italian “uccelli AND vento AND turbina” and Portuguese “pássaros AND vento AND turbina”.

These languages cover the following countries with wind energy developments, according to AWEA (2003): Germany, Spain, Denmark, Italy, Netherlands, UK, Sweden, France, Portugal, Austria, Ireland, Belgium, Finland, Norway, Switzerland, Australia, Morocco and others with one of these languages in official use. Internet searches are unavailable in languages of other significant wind power nations including India, Japan, Greece, China and the Ukraine. However, the English language search may retrieve English language translations from these countries. For internet searches of relevant sites, we undertook “hand” (following links) or, where available, electronic site searches of the first 100 “hits” for each search engine within the meta-search. Articles identified by this process were assessed in the same manner as other articles.

#### *Other searches*

The RSPB library was hand searched. In addition, bibliographies of articles accepted for full text viewing and those in otherwise relevant secondary articles were searched. We also contacted recognised experts and current practitioners in the fields of applied

avian ecology and renewable energy technology to identify possible sources of primary data and to verify the thoroughness of our literature coverage.

### ***Inclusion criteria***

Specific inclusion criteria were based on the subject, intervention, outcome and comparator. The criteria were defined before the studies were assessed. They were refined and narrowed in scope prior to data extraction as described in question formulation. The review specific criteria were:

- *Subjects(s)* studied – any bird species (information was extracted on Falconiformes, Accipitriformes, Anseriformes, Passeriformes and Charadriiformes except *Laridae*).
- *Intervention* used – commercial wind installations: wind farms and turbines.
- *Outcome(s)* – population size or distribution, breeding success, population mortality rate, recruitment rate, turnover rate, immigration rate, emigration rate, demography, dispersal behaviour, collision mortality, displacement disturbance, movement impeded, and habitat loss or damage. (Only information on bird abundance was extracted).
- *Comparator* – appropriate controls (e.g. reference areas) or pre-development comparators

### ***Relevance assessment***

Initial screening of references for relevance using the inclusion criteria was performed by one reviewer (CFC), with reference to a second (ASP) in cases of uncertainty. Where there was insufficient information it was assumed that references were relevant. Two reviewers (CFC & ASP) independently assessed relevance at full text.

### ***Study quality***

Study quality assessment was carried out at full text by critical evaluation of methodology using a hierarchy of evidence adapted from models of the systematic review process used in medicine and public health (Stevens & Milne 1997, Pullin & Knight 2003). Assessment of selection bias, performance bias, assessment bias and attrition bias was also incorporated in study quality assessment (Khan *et al.* 2001) using a review specific study quality instrument (appendix 1). This examined factors likely to confound the observed relationships if they vary unequally in treatment and control groups. In the case of bird abundance and windfarms these are likely to include: initial abundance of species, functional types present, habitat type, size of area, site management techniques, turbine number and power. Study quality assessment was performed by one reviewer (GS), with reference to a second (ASP) in cases of uncertainty. The assessments of study quality are described in the table of included studies (appendix 2).

### *Data extraction*

Relevant data were extracted by one reviewer (GS), with reference to a second (ASP) in cases of uncertainty into an MS Excel spreadsheet (Microsoft Corporation) and a table of included studies (appendix 2). For the purposes of data extraction a windfarm was considered as an experimental unit and information on the abundance of relevant taxon on windfarm and comparator sites was extracted, with variance derived from replicate observations.

### *Data synthesis*

Data synthesis was achieved through non-quantitative synthesis, complemented by meta-analysis and meta-regression. Non-quantitative synthesis consisted of tabulation of study characteristics and outcomes to highlight similarities and differences in key ecological, windfarm, methodological and outcome measures.

### *Handling of missing data*

Where variance data was unavailable, range was used to estimate the standard deviation. The standard deviation conversion factor was dependent upon sample size (Table 1) with standard deviation approximated by division of the range with the conversion factor. Where range data was unavailable, sensitivity analyses were performed. The largest standard deviation from other studies was doubled to provide a conservative down-weighted variance measure. Further sensitivity analyses were performed using the mean standard deviation from other studies to provide average weighting. Where sample sizes were unknown, average sample size was substituted. Likewise, where windfarm characteristics were missing they were substituted by average values. On occasion, samples had standard deviations of zero. These were replaced with standard deviations of 0.001 in order to run meta-analytical software.

**Table 1.** Relationship between sample size and standard deviation conversion factor.

<b>Sample size</b>	<b>Conversion Factor</b>
2	1.5
3-6	2.5
7-12	3
13-30	4
31-150	5
151-500	6
>501	6.5

### *Synthesis of data by individual windfarm.*

Species information within individual windfarms was combined using Random effects meta-analyses based on weighted mean difference (WMD) where all data on means, sample sizes and variance was available.

### *Combination of data across windfarms*

Species information was synthesised across windfarms in three ways:

1) Individual data points within windfarms were used as pseudoreplicates and all data was pooled and combined using random effects meta-analysis based on standardised

mean difference (SMD). Sensitivity Analyses were performed where variance and sample size data was missing (Khan *et al.* 2001, Morton *et al.* 2001). It is better to impute values for missing standard deviations for continuous outcomes from primary studies so study effect sizes may be estimated and pooled in reviews rather than exclude results because of missing values, making certain to explicitly describe the imputation methods used (Wolf & Guevara 2001). Missing data was substituted for by: a) two times the largest standard deviation of other data points and average sample size resulting in conservative down-weighting and b) the average standard deviation and sample size of other points resulting in average weighting.

2) Data was aggregated within windfarms and combined to produce aggregate effect sizes that were then combined using random effects SMD meta-analysis. The treatment and control means, standard deviations and sample size of species within a study were used to generate study treatment and control means, standard deviations and sample sizes to calculate aggregate study effect sizes. Meta-analysis was performed on complete data with an additional sensitivity analysis including non-independent and dummy variance data with conservative down-weighting.

3) Aggregate effect sizes were also produced based on species number rather than spatial or temporal replication. The treatment and control mean of species within a study were used to generate study treatment and control means. Standard deviations were derived from within study means and the number of species represented the sample size. The aggregate effect sizes were combined in SMD meta-analyses performed on complete data with an additional sensitivity analysis including non-independent and dummy variance data with conservative down-weighting.

#### *Assessment of heterogeneity and bias*

Heterogeneity was assessed by inspection of Forrest plots of the estimated treatment effects from the studies along with their 95% confidence intervals and by formal tests of homogeneity undertaken prior to each meta-analysis (Thompson and Sharp 1999). Likewise, each meta-analysis was accompanied by a Funnel plot (plots of effect estimates versus the inverse of their standard errors). Asymmetry of the funnel plot may indicate publication bias and other biases related to sample size, though it may also represent a true relationship between trial size and effect size. A formal investigation of the degree of asymmetry was performed using the method proposed by Egger *et al.* (1997).

#### *Exploration of Reasons for heterogeneity*

Three potential sources of heterogeneity were defined *a priori* as primary reasons for variation in effect size. We hypothesised that the effect of windfarms on bird abundance differs according to the species of bird, the number of turbines in the installation and the power of turbines in the installation. The association of these factors with estimated effects were examined by performing univariate random effects SMD meta-regression on data with no missing values in Stata version 8.2 (Stata Corporation, USA) using the program Metareg (Sharp 1998).

#### *Multivariate exploration of reasons for heterogeneity*

Taxon, turbine number and power, location, latitude, habitat type, size of area, time since operation, migratory status of the species and quality of evidence were defined as potential reasons for heterogeneity for exploratory analysis. These were

investigated in multivariate random effects SMD meta-regression on data with no missing values in Stata version 8.2 (Stata Corporation, USA) using the program Metareg (Sharp 1998).

## **Results**

### ***Review statistics***

Searching retrieved over 2845 bibliographic references including duplicates, of which, 124 were accepted for full text viewing after initial screening of title and abstract. This was inclusive of articles where there was insufficient information to make a decision without reference to the full texts. After full text viewing, 104 were excluded as they did not fulfil the inclusion criteria (54 of these articles presented data pertaining to outcomes other than bird abundance (including mortality) and provide potential material for subsequent related systematic reviews).

Of the remaining 20 articles, five were duplicate publications based on data from the same sites, whilst 15 presented independent data on changes in bird abundance and were accepted for this review. Two articles presented data on more than one windfarm, whilst one was not suitable for quantitative analysis, thus data from 19 windfarms were available for synthesis (Table 2, appendix 2).

### ***Study quality***

Six datasets were based on 'before and after' time series, whilst 13 were site-comparisons. Eight datasets had potentially important confounding factors resulting from variation between treatment and control at baseline or from changes concurrent with windfarm operation (Table 2, appendix 2). Study sample sizes varied from two to 228 replicates. The rigour of observations was variable as measured in terms of replication and objectivity (appendix 2).

### ***Study characteristics***

Thirteen of the windfarms were located in Europe with the remainder from North America. Ten were sited inland, seven were coastal and two were offshore. The bird taxon recorded and the habitat surrounding the windfarms are listed in Table 2. Turbine number ranged from 1 to 6500, whilst turbine power ranged from 85kW to 750kW. Time from first operation to monitoring varied from one to 12 years (Table 2, appendix 2).

**Table 2.** The ecological, windfarm and methodological characteristics of the included studies.

Data set	Ecological characteristics				Windfarm characteristics			Methodological characteristics			Analysis
	Location	Taxon	Taxon number	Habitat	Turbine Power (KW)	Turbine number	Time since operation (years)	Experimental design	Confounding factors	Unit of replication	
De Lucas, Janss, <i>et al.</i> (2004)	Southern Spain, inland	Accipitriformes, Falconiformes & Passeriformes	5	Scrub / brushwood	116	86	2	Site comparison	Treatment has lower vegetation cover than control.	Temporal replication of one transect in treatment and control	Included in all analyses
Guillemette <i>et al.</i> (1998)	Denmark, offshore	Anseriformes	2	Marine	500	10			Mussel availability is correlated with sea duck decline	Temporal replication of observations in treatment and control	
Hunt, et al (1995)	California, inland	Accipitriformes	1	Grassland	85	6500	12		Ground squirrels are removed from the windfarm site which may account for raptor decline	Spatial replication of observations in treatment and control averaged over time	
Johnson, Erickson <i>et al.</i> (2000) 1.	Minnesota, inland	Accipitriformes, Anseriformes, Charadriiformes, Falconiformes & Passeriformes	96	Arable	342	73	3		None known	Spatial replication of observations in treatment and control averaged over time	Included only in SMD sensitivity analysis as the three data sets are not independent sharing the same control. This is compounded by the lack of variance data.
Johnson, Erickson <i>et al.</i> (2000) 2.					750	143	2				
Johnson, Erickson <i>et al.</i> (2000) 3.					750	138	1				
Johnson, Young <i>et al.</i> (2000)	Wyoming, inland	71	Scrub / brushwood	647	105						
Kerlinger (2002)	Vermont, inland	Accipitriformes, Falconiformes & Passeriformes	54	Forest	550	11	Time series	Spatial replication of observations before and after windfarm construction			

Ketzenberg <i>et al.</i> (2002) 1.	Saxony, coastal	Charadriiformes	4	Arable	550	17	4	Time series	Changes in land use occurred which could confound the results	observations before and after windfarm construction	Included only in SMD sensitivity analysis as there is no variance or sample size data with which to weight the study at the individual species level.
Ketzenberg <i>et al.</i> (2002) 2.			3			34					
Ketzenberg <i>et al.</i> (2002) 3.			4			17					
Ketzenberg <i>et al.</i> (2002) 4.											
Larsson (1994)	Sweden, offshore	Anseriformes	6	Marine	220	1	1	Site comparison	None known	Spatial replication of observations in treatment and control averaged over time.	Included in all analyses
Meek <i>et al.</i> (1993)	Orkney, inland	Anseriformes, Charadriiformes & Passeriformes	3	Moorland	275	2	6		Variation in habitat and management practices between the windfarm and control could confound the results.		Excluded from WMD meta-analysis as there are <3 species. Included in all SMD analyses
Phillips (1994)	Wales, inland	Accipitriformes, Anseriformes, Falconiformes & Passeriformes	53	Moorland	450	22	1		None known	Spatial replication of observations in treatment and control	Included in all analyses
Schmidt <i>et al.</i> (2003)	Colorado, inland		38	Grassland	Unknown						Included only in SMD Sensitivity analysis as there is no windfarm characteristics data
Still <i>et al.</i> (1996)	England, coastal	Anseriformes, Charadriiformes	2	Urban	300	9	2	Time series	Changes in climate occurred which could confound the results	Temporal replication of observations before and after windfarm construction	Included in all analyses
Winkelman (1989)	Holland, coastal		6	Arable		25	3	Site comparison	None known	Temporal replication of observations in treatment and control after windfarm construction	
Winkelman (1992)	Holland, coastal		Anseriformes, Charadriiformes, Passeriformes	9		Arable	18		1	Habitat changes occurred (increase in crops) which confound the baseline but are equal in treatment and control	

## Outcome of the review

### *Individual windfarms.*

Nine windfarms had complete data available for extraction, although three of these windfarms presented data on fewer than three bird species and were excluded from this analysis. Synthesis of within windfarm data across species using random effects WMD meta-analysis resulted in negative pooled effect sizes, of which two are significant. There was significant heterogeneity within three studies and significant bias within one. One taxon had a significant positive effect size, whilst 12 taxon had significant negative effect sizes (Table 3).

**Table 3.** DerSimonian-Laird pooled effect sizes from weighted mean difference meta-analysis across species within windfarms. Heterogeneity is indicated by Q (Thompson and Sharp 1999), whilst bias is indicated by the Egger test (Egger *et al.* 1997). Heterogeneity, bias and individual taxon were considered significant at  $P < 0.05$ .

study	Main Pooled Effect			Individual taxon effects		
	Pooled Effect size	P	Q	bias	Significant positive effect size	Significant negative effect size
De Lucas et al. (2004)	-0.699	0.383	<b>111.269</b>	-2.316	-	<i>Passeriformes, Milvus migrans</i>
Larsson (1994)	<b>-2.673</b>	<b>0.001</b>	8.109	1.492	-	<i>Clangula hyemalis, Mergus serrator</i>
Meek et al.(1993)	-3.762	0.762	<b>70.245</b>	insufficient strata	Charadriiformes	Passeriformes
Phillips (1994)	$-5.6 \times 10^{12}$	0.999	50.918	0.046	-	-
Winkelman (1992)	<b>-275.771</b>	<b>&lt; 0.0001</b>	<b>263.339</b>	<b>-5.212</b>	-	<i>Anas platyrhynchos, Anas penelope, Fulica atra, Vanellus vanellus, Pluvialis apricaria, Numenius arquata, Haematopus ostralegus, Sturnus vulgaris</i>
Winkelman (1989)	-0.660	0.057	2.738	0.470	-	-

### *Combining windfarms with pseudoreplication*

The complete datasets (including datasets with  $< 3$  species) were pooled and combined using Random effects SMD meta-analysis resulting in a significant negative pooled effect size. ( $d = -0.328$ , 95% CI = -0.490 to -0.166,  $P < 0.0001$ ). There was significant heterogeneity ( $Q = 349.958$ ,  $P < 0.0001$ ) but no significant bias (Egger test = -0.297,  $P = 0.371$ ).

Sensitivity analyses were performed and the results remained similar with the addition of down-weighted data (two times the largest known standard deviation imputed where it was missing) and non-independent data. The effect size was negative albeit it smaller, heterogeneity was not significant but bias was ( $d = -0.033$ , 95% CI = -0.055 to -0.011,  $P = 0.0028$ ,  $Q = 464.531$ ,  $P = 0.9972$ , Egger test = -0.303,  $P = 0.015$ ).

When the data with missing variance and non-independent data was given average weighting (average known standard deviation imputed where it was missing), the effect size was comparable but the result was not significant. Neither heterogeneity or bias was significant ( $d = -0.022$ , 95% CI = -0.046 to 0.0004,  $P = 0.0549$ ,  $Q = 601.645$ ,  $P = 0.070$ , Egger test = -0.121,  $P = 0.396$ ).

### *Synthesis of data across windfarms with aggregation bias*

Data was aggregated within windfarms and combined to produce aggregate effect sizes which were then combined using Random effects SMD meta-analysis. When

aggregate averages were derived using individual within study means, samples sizes and standard deviations, the pooled effect size was negative and significant ( $d = -0.712$ , 95% CI = -1.076 to -0.348,  $P = 0.0001$ ). Heterogeneity was not significant ( $Q = 14.713$ ,  $P = 0.065$ ) and bias was not significant (Egger test = -0.114,  $P = 0.874$ ). Sensitivity analysis was performed and the results remained similar with the addition of down-weighted data (two times the largest known standard deviation imputed where it was missing) and non-independent data. The effect size was negative and significant. Heterogeneity was significant but bias was not. ( $d = -0.257$ ,  $P = 0.0235$ ,  $Q = 47.586$ ,  $P = 0.0002$ , Egger test = 0.569,  $P = 0.447$ ).

Aggregate effect sizes were also calculated with species as replicates. Aggregate averages and standard deviations were derived using within study means whilst the number of species represented sample size. The pooled effect size was negative and significant ( $d = -0.489$ , 95% CI = -0.944 to -0.033,  $P = 0.035$ ). Heterogeneity and bias were not significant ( $Q = 10.972$ ,  $P = 0.203$ , Egger test = -1.110,  $P = 0.105$ ). Sensitivity analysis was performed with the addition of down-weighted data (two times the largest known standard deviation imputed where it was missing) and non-independent data. The pooled effect size was negative but not significant whilst heterogeneity was significant but bias was not ( $d = -0.240$ ,  $P = 0.089$ ,  $Q = 45.358$ ,  $P = 0.0004$ , Egger test = -0.680,  $P = 0.4069$ ).

#### *Exploration of Reasons for heterogeneity*

Univariate meta-regression was used to investigate *a priori* reasons for heterogeneity in results. Bird taxon had a significant impact on the effect of windfarms on bird abundance with Anseriformes experiencing greater declines in abundance than other bird groups, followed by Charadriiformes, Falconiformes and Accipitriformes and Passeriformes (Table 4). Turbine number (size of windfarm) did not have a significant impact on bird abundance whilst turbine power had a very weak but statistically significant effect with low power turbines resulting in greater declines in abundance than high power turbines (Table 4).

**Table 4.** Univariate meta-regression coefficients and significance for taxon, turbine number and turbine power.

Explanatory variable	Coefficient	Standard error	Z	P	Lower CI	Upper CI
Taxon	0.290	0.070	4.11	<b>0.0001</b>	0.151	0.428
Turbine number	0.0001	0.0001	-0.92	0.358	-0.0004	0.0001
Turbine power	0.002	0.0007	2.91	<b>0.004</b>	0.0007	0.003

Bird taxon, turbine number and turbine power were combined with habitat type, the migratory nature of the species, latitude, location, size of area, time since operation of windfarm and data quality using multivariate meta-regression. Time since start of windfarm operation had a significant impact on bird abundance with longer operating times resulting in greater declines in abundance than short operating times (Table 5). Latitude had a very weak but statistically significant effect with high latitudes resulting in greater declines in abundance than low latitudes (Table 5).

**Table 5.** Multivariate meta-regression coefficients and significance for taxon, location, latitude, turbine number, turbine power, habitat type, size of area, time since operation, migratory status and data quality.

Explanatory variable	Coefficient	Standard error	Z	P	Lower CI	Upper CI
Taxon	0.015	0.135	0.11	0.912	-0.250	0.280
Location	-0.494	0.474	-1.04	0.297	-1.424	0.435
Latitude	-0.099	0.032	-3.11	<b>0.002</b>	-0.162	-0.036
Turbine number	-0.009	0.005	-1.55	0.121	-0.020	0.002
Turbine power	0.002	0.002	1.15	0.248	-0.001	0.007
Habitat type	0.158	0.166	0.96	0.340	-0.166	0.484
Size of area	0.286	0.201	1.42	0.156	-0.109	0.681
Time since operation	0.519	0.155	3.34	<b>0.001</b>	0.214	0.823
Migrant	-0.061	0.071	-0.86	0.389	-0.202	0.078
Data quality	0.030	0.093	0.33	0.745	-0.153	0.214

Many of the variables investigated in the multivariate meta-regression are correlated with each other. There are 16 statistically significant ( $P < 0.01$ ) correlations between the ten variables with taxon and location significantly correlated with effect size (Table 6).

**Table 6.** Correlation coefficients of the explanatory variables and effect size weighted by the inverse standard error of effect size. The p value is indicated in italics. Significant results (P<0.01) are in bold.

Taxon	1										
Location	<b>0.777</b> <i>0.00001</i>	1									
Latitude	-0.152 <i>0.159</i>	<b>-0.397</b> <i>0.0001</i>	1								
Turbine number	0.002 <i>0.981</i>	0.066 <i>0.542</i>	-0.177 <i>0.099</i>	1							
Turbine power	<b>0.295</b> <i>0.005</i>	0.023 <i>0.832</i>	<b>0.809</b> <i>0.00001</i>	-0.179 <i>0.096</i>	1						
Habitat type	-0.248 <i>0.02</i>	0.027 <i>0.799</i>	<b>-0.726</b> <i>0.00001</i>	0.034 <i>0.748</i>	<b>-0.842</b> <i>0.00001</i>	1					
Size of area	0.119 <i>0.271</i>	0.15 <i>0.163</i>	-0.097 <i>0.367</i>	<b>0.984</b> <i>0.00001</i>	-0.034 <i>0.754</i>	-0.099 <i>0.361</i>	1				
Time since operation	-0.255 <i>0.016</i>	0.034 <i>0.752</i>	-0.221 <i>0.0391</i>	<b>0.68</b> <i>0.00001</i>	<b>-0.421</b> <i>0.00001</i>	0.223 <i>0.037</i>	<b>0.606</b> <i>0.00001</i>	1			
Migrant	0.171 <i>0.113</i>	0.164 <i>0.128</i>	<b>-0.294</b> <i>0.005</i>	0.091 <i>0.4</i>	-0.16 <i>0.138</i>	0.139 <i>0.198</i>	0.087 <i>0.421</i>	-0.002 <i>0.982</i>	1		
Data quality	<b>0.308</b> <i>0.003</i>	0.009 <i>0.931</i>	<b>0.721</b> <i>0.00001</i>	-0.104 <i>0.338</i>	<b>0.854</b> <i>0.00001</i>	<b>-0.913</b> <i>0.00001</i>	0.043 <i>0.692</i>	<b>-0.424</b> <i>0.00001</i>	-0.1 <i>0.353</i>	1	
Effect size	<b>0.371</b> <i>0.0004</i>	<b>0.465</b> <i>0.00001</i>	-0.138 <i>0.199</i>	-0.082 <i>0.449</i>	0.156 <i>0.1475</i>	-0.1371 <i>0.2055</i>	-0.02 <i>0.853</i>	-0.021 <i>0.843</i>	-0.0004 <i>0.996</i>	0.122 <i>0.256</i>	1
	Taxon	Location	Latitude	Turbine number	Turbine power	Habitat type	Size of area	Time since operation	Migrant	Data quality	Effect size

## Discussion

Our analyses suggest that windfarms can have a negative impact on bird abundance especially amongst Anseriformes and Charadriiformes. However, there is statistically significant heterogeneity in results, and on occasion windfarms do not have a negative impact for individual taxon. For example, Charadriiformes (*Calidris alpina* and *Pluvialis apricaria*) have higher abundance at a windfarm site on Orkney than at a control although variation in habitat and management practices between the windfarm and control sites could explain this (Meek *et al.* 1993).

Pooling the data from the six windfarms and another three with a limited number of species using random effects SMD meta-analysis did not substantially alter the results. However, the addition of data from the ten windfarms with missing data did reduce the effect size with statistical significance dependent upon weighting. Although there are no hard and fast meta-analytical rules, the inclusion of all available data has been advocated by Wolf & Guevara (2001). The use of large standard deviations means that all data is utilised whilst allowing data based on known variance higher weighting. The use of all 19 datasets with down weighted missing value data is therefore probably of most value in providing an overall summary of the impact of windfarms on bird abundance suggesting that windfarms have a small negative impact on abundance. Given the heterogeneity underlying the pooled result this indicates that windfarms can, but do not necessarily, have negative impacts on bird abundance, depending on location.

This is consistent with the current consensus that windfarm location is of critical importance in avoiding deleterious impacts (Langston and Pullan 2003, Percival 2001). Many studies (Gill 2000a, b, DH consultancy 2000, Thomas 1999) suggest that windfarms do not have an impact on bird disturbance. Conversely mortality from bird strike is extremely high at Altamont (Hunt 1999, 2001, 2002) and Tarifa (Jans 2000). This has led to the recommendation, borne out by the current study, that wind farms should not be sited in statutorily designated sites, qualified international sites, national sites for nature conservation or other areas with large concentrations of birds such as migration crossing points or areas containing populations of species of conservation concern (Langston and Pullan 2003).

The SMD meta-analyses described are pseudoreplicated, because effect sizes have been generated for individual taxon and pooled across windfarms. Sensitivity analysis was undertaken to account for this and the pooled results are robust in so far as synthesis involving pseudoreplication produces similar results to synthesis involving different kinds of aggregation bias, both for the nine complete data sets and the 19 datasets with missing values imputed by two times the largest known standard deviation.

### *Exploration of Reasons for heterogeneity*

The consideration of heterogeneity is a critical aspect of systematic review (Thompson 1994, Bailey 1987) allowing the formation of testable hypotheses about ecological or windfarm characteristics that may have an impact on the effect of windfarms on bird abundance. Bird taxon monitored had a significant impact on the effect of windfarms on bird abundance with Anseriformes experiencing greater

declines in abundance than other bird groups, followed by Charadriiformes, Falconiformes and Accipitriformes and Passeriformes. This is consistent with the findings of the random effects WMD meta-analyses of individual windfarms. It is also consistent with the conclusions of Langston and Pullan (2003).

The duck species which had negative effect sizes included the sea ducks *Clangula hyemalis* (Long-tailed Duck), *Somateria mollissima* (Eider) and *Melanitta nigra* (Common scoter) which are thought to be particularly vulnerable to disturbance displacement, barrier to movement, collision and habitat damage impacts (Langston and Pullan 2003). Conversely Percival (2001) argues that the evidence concerning *S. mollissima* points to no impact on sea ducks although there is considerable uncertainty surrounding this conclusion. Charadriiformes were considered vulnerable to disturbance displacement and barrier to movement, Accipitriformes to disturbance displacement and collision, Passeriformes (especially nocturnal migrants) were considered vulnerable to collision (Langston and Pullan 2003). The meta-regression provides evidence that Anseriformes, especially sea ducks, are amongst the most vulnerable bird species to windfarm impacts.

Given the small sample size (87 data points, nine windfarms included in meta-regression) and magnitude of the correlation, low power turbines resulting in greater declines in abundance than high power turbines is not considered meaningful. This is consistent with the findings of Thomas (1999) who found no relationship between bird density and turbine size. The lack of strong relationships between effect size, turbine number and turbine power means it is not possible to resolve the debate about the relative impacts of few high powered turbines versus larger numbers of smaller low powered turbines. This is an important area for further work as future offshore wind installations are likely to consist of smaller numbers of high powered turbines (Gill *et al.* 1996, Langston and Pullan 2003).

Time since operation had a significant impact on the effect of windfarms on bird abundance with longer operating times resulting in greater declines in abundance than short operating times. This has important implications for further work (see below). It is also inconsistent with the theory that birds may become habituated to the presence of windfarms (Gill *et al.* 1996, Langston and Pullan 2003). The meta-regression provides evidence that deleterious impacts are likely to persist or worsen with time suggesting that bird habituation to windfarms should be considered with some scepticism. There was also a very weak but statistically significant effect of latitude. Given the small sample size and magnitude of the correlation this is not considered meaningful.

Many of the variables investigated in the multivariate meta-regression are correlated with each other. There are 16 statistically significant correlations between the ten variables thus it is very difficult to attribute declines in bird abundance with any one variable. Both taxon and location are significantly correlated with effect size and each other. This reflects the nature of the data. Windfarms with large numbers of Anseriformes are located offshore, whilst Charadriiformes are associated with coastal windfarms. It is therefore not possible to disentangle these variables. This is reflected in the management recommendations. Multivariate meta-regression sensitivity analyses were run. Anseriformes were excluded from the dataset and the same patterns remained. Meta-regression was also attempted on all 19 datasets but the algorithm failed to reach an asymptote.

### *Review limitations*

This review is concerned solely with the impact of windfarms on bird abundance. It does not directly consider any outcome measures other than population abundance. There is a large body of literature on bird mortality associated with turbine strike. A further review of mortality would be required to ascertain which ecological and wind farm characteristics are associated with high mortality.

The review was based on comparison of treatment and control or before and after impact data. Ideally, synthesis would be undertaken using rates of change derived from randomized replicated studies. This data was largely unavailable and it was considered inappropriate to synthesise rates of change with different abundances where it was potentially available.

The review does not consider scale effects other than windfarm size. There is potential for long turbine strings to disrupt ecological links by displacing birds moving between feeding, breeding and roosting areas (Langston and Pullan 2003, Percival 2001). This could not be investigated in multivariate meta-regression as there was insufficient reporting of turbine layout for efficient and standardised data extraction and analysis. Furthermore, it is recognised that multiple installations may have a cumulative impact (Langston and Pullan 2003). Larger sample sizes would be required to ascertain cumulative impacts. Recommendations regarding turbine layout and appropriate distance between individual windfarms cannot be derived from the data that is currently available. This represents an important knowledge-gap.

The scope of this review was global but the retrieved data may not accurately reflect the totality of all windfarms. A total of 217 species (appendix 3) contributed to the datasets. There was not enough information for meaningful synthesis of taxon other than Accipitriformes, Anseriformes, Charadriiformes (excluding *Laridae*), Falconiformes and Passeriformes. It was considered inappropriate to combine data on *Laridae* with other Charadriiformes given the ecological variation between these groups and there was insufficient information on *Laridae* to include them as a functionally meaningful taxonomic group in the analysis.

Thirteen of the wind farms were located in Europe with the remainder from North America thus the applicability of the results to many areas remains unknown. However, Europe and North America are the areas where windfarms have been pioneered thus limited additional information may be available from other areas.

In spite of the systematic and extensive search strategy, not all information on windfarms was included in the review. Much of existing data come from grey literature, an unspecified proportion of which is not in the public domain. Client confidentiality is a major problem often preventing dissemination of Environmental Impact Assessments on Windfarm installations. Legislation should be modified to enable the quality of this work to be assessed and results incorporated with available data. It has been suggested that the Renewable and Energy Efficiency Organisation (now incorporated into Future Energy Solutions) should maintain a common library of windfarm data to improve dissemination (Percival 2001). Should sufficient quantities of information be released in future, and other work come to light, the review can undergo substantive amendment in order to update it.

Ten windfarms were sited inland, seven were coastal and two were offshore. The robustness of conclusions regarding offshore windfarms is therefore constrained by data availability. This is a recognised problem (Gill 1996, Langston and Pullan 2003) as there are currently only eight operational offshore windfarms (Percival 2001). The development of offshore windfarms is in its infancy and there is therefore a dearth of information in an area where it is most required. Other factors restrict the applicability of results from offshore windfarms. The flock sizes of birds in both offshore studies were small and it is believed that small flocks are less sensitive to disturbance impacts than large flocks (Langston and Pullan 2003). Additionally, the distribution of sea ducks is very variable and related to food availability (Guillemette, Larsen and Clausager 1999, Percival 2001, Langston and Pullan 2003). These factors have important implications suggesting that both the impact of windfarms on sea ducks and variability may be larger than the current work predicts. There is a limited extent of shallow water suitable for the construction of offshore windfarms and it is in this shallow water that large aggregations of sea ducks are found prompting the suggestion that moving turbines further offshore needs to be considered (Langston and Pullan 2003). This recommendation seems sensible in the light of the above, although the impact of such deep offshore developments would require rigorous monitoring.

Eight datasets had potentially important confounding factors resulting from variation between treatment and control at baseline or from changes concurrent with wind farm operation. The most critical of these is the effect of food availability discussed above. Study sample sizes varied from two to 228 replicates. The rigour of observations was variable as measured in terms of replication and objectivity. The problems of few studies, lack of comparators, inadequate duration of follow up and poor study quality were recognised by Langston and Pullan (2003) and remain problematic. Langston and Pullan (2003) recommend that BACI (Before-After-Control-Impact) studies include one year of monitoring before impact as a minimum but preferably two to three years to ensure that the annual cycle of a species is adequately represented. They also recognise that long term monitoring is necessary and recommend follow up of five to ten years. The current work indicates that these recommendations represent minimal acceptable practice rather than best practice highlighting both the necessity for long term studies and a high degree of replication.

Thus although this systematic review has allowed a more objective appraisal of the evidence than traditional narrative reviews, there is still uncertainty about the impact of windfarms on bird abundance and a clear requirement for further work.

## **Reviewers' conclusion**

### *Implications for conservation*

***Available evidence suggests that windfarms reduce the abundance of many bird species at the windfarm site. There is some evidence that Anseriformes (ducks) experience greater declines in abundance than other bird groups suggesting that a precautionary approach should be adopted to windfarm developments near aggregations of Anseriformes and to a lesser extent Charadriiformes particularly in offshore and coastal locations. There is also some evidence that the impact of windfarms on bird abundance becomes more pronounced with time, suggesting that***

*short term bird abundance studies do not provide robust indicators of the potentially deleterious impacts of windfarms on bird abundance.*

*These results should be interpreted with caution given the small sample sizes and variable quality data. More high quality research and monitoring is required, in particular, long term studies with independent controls and variance data. Pending further research, if impacts on bird abundance are to be avoided, the available evidence suggests that windfarms should not be sited near populations of birds of conservation importance, particularly Anseriformes.*

*Implications for further research.*

*Environmental impact assessments of wind farms require long term monitoring. The use of BACI designs has been advocated. Ideally these should incorporate replicated and balanced experimental designs, preferably with a truly random sampling procedure or some thought given to minimising the potential for confounding effects. Although such monitoring is costly, the value of unreplicated non-randomised short term monitoring is negligible. The impact of offshore windfarms in particular represents a knowledge gap requiring further needs led research as do the cumulative impact of windfarms and the impact of turbine layout.*

### **Acknowledgements**

We would like to thank all the authors and organisations who responded to our enquiries; Karina Tveen Jensen, Harma Brondijk, Marijke Albus, Eugenio Sanchez Moran and Ulrike Lange for translation; Rod Taylor and Khalid Khan for statistical advice; English Nature and RSPB personnel especially Rowena Langston for comments, support and access to literature; Colleagues at the Centre for Evidence Based Conservation and the School of Biosciences, University of Birmingham especially Zoe Davies, Graham Martin, Steve Portugal, Jim Reynolds and Claire Tyler.

### **References**

AWEA (2003). *Global Wind Energy Market Report*. Internet publication  
<http://www.awea.org/pubs/documents/globalmarket2003.pdf>

Bailey, K. (1987) Inter-study differences: how should they influence the interpretation and analysis of results? *Statistical medicine* **6**, 351-8.

BWEA (2004). <http://www.bwea.com/map/index.html>

Campbell, B., Lack. E. (1985). *A Dictionary of Birds*. Vermillion: Buteo Books.

Crockford, N.J. (1992). A review of the possible impacts of wind farms on birds and other wildlife. *JNCC Report 27*. Joint Nature Conservation Committee, Peterborough.

DH consultancy (2000) *Windy Standard Wind farm, Dumfries and Galloway Breeding Bird survey 2000*. Cited by Langston, R.H.W. and Pullan J.D. 2003. *Windfarms and birds: an analysis of windfarms on birds, and guidance on environmental assessment criteria and site selection issues*. RSPB/BirdLife report.

Egger M, Davey-Smith G, Schneider M, Minder C. (1997) Bias in meta-analysis detected by a simple graphical test. *British Medical Journal* **315**, 629-34.

Gill, J.P. (2000a). *Baseline breeding bird survey of the Dunlaw wind farm. Report to Renewable Energy Systems Ltd.* Environmentally Sustainable Systems, Edinburgh. Cited by Langston, R.H.W. and Pullan J.D. 2003. *Windfarms and birds: an analysis of windfarms on birds, and guidance on environmental assessment criteria and site selection issues.* RSPB/BirdLife report.

Gill (2000b) *Changes in breeding birds at Dunlaw wind farm. Report to Renewable Energy Systems Ltd.* Environmentally Sustainable Systems, Edinburgh. Cited by Langston, R.H.W. and Pullan J.D. 2003. *Windfarms and birds: an analysis of windfarms on birds, and guidance on environmental assessment criteria and site selection issues.* RSPB/BirdLife report.

Gill, J.P., Townsley, M. and Mudge, G.P. (1996). Review of the impacts of wind farms and other aerial structures on birds. *Scottish Natural Heritage Review No. 21*.

Guillemette, M., Larsen, J.K. & Clausager, I. (1999). *Assessing the impact of Tunø Knob wind park on sea ducks: the influence of food resources.* Neri Technical report no **263**.

Jans, G. (2000) Bird Behaviour in and near a windfarm at Tarifa, Spain: Management Considerations. *Proceedings of the National Avian Wind Power planning meeting* **111**, 110.114. [www.nrel.gov](http://www.nrel.gov).

Khan, K.S., ter Riet, G., Glanville, J., Sowden, A.J. and Kleijnen, J. (eds.) 2001. Undertaking systematic reviews of research on effectiveness. *NHS Centre for Reviews and Dissemination, report number 4*, 2<sup>nd</sup> edition, University of York.

Knox, A.G. (1992) *Checklist of Birds of Britain and Ireland.* British Ornithologists Union

Langston, R.H.W. and Pullan J.D. 2003. *Windfarms and birds: an analysis of windfarms on birds, and guidance on environmental assessment criteria and site selection issues.* RSPB/BirdLife report.

Morton, S., P. Shekelle, et al. (2001). Meta-analysis of messy data: problems and solutions from a meta-regression analysis of spinal manipulation for low back pain. *Cochrane* **1**: op024.

Percival, S.M. (2001) Assessment of the effects of offshore wind farms on birds. *ETSU W/13/00565/REP DTI/Pub URN01/1434*, Ecology Consulting.

Pullin, A.S. & Knight, T.M. 2003. Support for decision making in conservation practice: an evidence-based approach. *Journal for Nature Conservation* **11**, 83-90.

SGS Environment (1996). A review of the impacts of wind farms on birds in the UK. *ETSU W/13/00426/REP***1,2,3**.

Sharp, S. (1998) Meta-analysis regression: statistics, biostatistics, and epidemiology. *Stata Technical Bulletin*.**42**, 16-22.

Stevens, A. and Milne, R. (1997). The effectiveness revolution and public health. In: G. Scally (Ed.) *Progress in Public Health*, p197-225. Royal Society of Medicine Press, London.

Thomas, R. (1999) An Assessment of the Impact of Wind Turbines on Birds at Ten Windfarm Sites in the UK. *Sustainable Development International*: 215-220.

Thompson, S.G. (1994) Why sources of heterogeneity in meta-analysis should be investigated. *British Medical Journal* **309**, 1351-5.

Thompson, S.G, and Sharp, S.J. (1999). Explaining heterogeneity in meta-analysis: a comparison of methods. *Statistics in Medicine*, **18**(20), 2693-708.

United Nations Framework Convention on Climate Change (2005) [www.unfccc.int](http://www.unfccc.int).

Wolf, F. and J. Guevara (2001). Imputation of missing data in systematic reviews: so what is the standard deviation? *Cochrane* **1**: pa007.

## Appendices

### *Appendix One: Windfarm Quality Assessment Instrument*

Bias and generic data quality features	Specific data quality features	Quality element	Quality score	
Selection and Performance bias: Study Design	NA	Randomized controlled Trial	<b>80</b>	
		Quasi-RCT (a trial applying a pseudo random allocation mechanism)	<b>70</b>	
		Controlled Trial	<b>60</b>	
		Historical CT (data for the control arm comes from archives not from current experimental observation)	<b>50</b>	
		Site comparison	<b>40</b>	
		Time Series	<b>30</b>	
		Interrupted time series	<b>20</b>	
		Expert Opinion / Questionnaire / data without comparator	<b>10</b>	
Selection and Performance bias: Baseline comparison (heterogeneity between treatment and control arms with respect to defined confounding factors before treatment)	Factors: Abundance of species	Treatment and control arms homogenous	<b>2</b>	
		Treatment and control arms not comparable with respect to confounding factors OR insufficient information	<b>0</b>	
	Functional types present (raptors, waders, wildfowl)	Treatment and control arms homogenous	<b>1</b>	
		Treatment and control arms not comparable with respect to confounding factors OR insufficient information	<b>0</b>	
	Location (coastal or inland)	Treatment and control arms homogenous	<b>1</b>	
		Treatment and control arms not comparable with respect to confounding factors OR insufficient information	<b>0</b>	
	Habitat type	Treatment and control arms homogenous	<b>1</b>	
		Treatment and control arms not comparable with respect to confounding factors OR insufficient information	<b>0</b>	
	Size of area	Treatment and control arms homogenous	<b>1</b>	
		Treatment and control arms not comparable with respect to confounding factors OR insufficient information	<b>0</b>	
	Selection and Performance bias: Intra treatment variation (heterogeneity within both treatment and control arms with respect to defined confounding factors during treatment)	Factors: Functional types present (raptors, waders, wildfowl)	No heterogeneity within treatment and control arms	<b>1</b>
			Replicates within treatment and control arms not comparable	<b>0</b>
Location (coastal or inland)		No heterogeneity within treatment and control arms	<b>1</b>	
		Replicates within treatment and control arms not comparable	<b>0</b>	
Turbine type		No heterogeneity within treatment and control arms	<b>1</b>	
		Replicates within treatment and control arms not comparable	<b>0</b>	
Habitat type		No heterogeneity within treatment and control arms	<b>1</b>	
		Replicates within treatment and control arms not comparable	<b>0</b>	
Size of area		No heterogeneity within treatment and control arms	<b>1</b>	
		Replicates within treatment and control arms not comparable	<b>0</b>	
Selection and Performance bias: Measurement of Co-interventions		site management techniques	Factor equal in treatment and control	<b>1</b>
			Factor not equal or unreported	<b>0</b>
Assessment bias: Measurement of outcome	Replication, parameter of abundance (accuracy)	Well replicated objective parameter of abundance used (>4 replications)	<b>4</b>	
		Replicated objective parameter of abundance used (1 – 4 replications)	<b>2</b>	
		Unreplicated observations or subjective parameter of abundance used	<b>0</b>	
Attrition bias: Assessment of treatment effect on sample number	NA	No losses to follow up	<b>2</b>	
		Minor (<20%) losses to follow up	<b>1</b>	
		Major (>20%) losses to follow up	<b>0</b>	

**Appendix Two: Table of included studies.**

<b>Study</b>	De Lucas, M., Janss, G.F.E & Ferrer, M. (2004). The effects of a wind farm on birds in a migration point: the Strait of Gibraltar. <i>Biodiversity and Conservation</i> <b>13</b> (2): 395-407.		
<b>Methods</b>	Bird counts along one transect repeated in time in treatment and control site.		
<b>Population and co-intervention</b>	Functional type of birds: Accipitriformes, Falconiformes and Passeriformes. Location: Tarifa, Southern Spain, inland. Windfarm design: 86 turbines with an average output of 116kW per turbine. Habitat type: brushwood and <i>Quercus</i> spp. Size of area: Wind farm study area transect is 2780m long. Area is defined as 2.7Km <sup>2</sup> . Site management techniques: unknown. Timescale: monitoring from July 1994 to September 1995. operation began in 1992 according to renewable energy yearbook 1993. Timescale = 2 years.		
<b>Outcome (Abundance)</b>	Mean number birds/km along one transect replicated through time . n=228, sd derived from range.		
	<b>Species</b>	<b>Treatment (windfarm)</b>	<b>Control</b>
	Passeriformes	8.5	69
	<i>Gyps fulvus</i>	8.88	5.23
	<i>Circaetus gallicus</i>	0.92	0.72
	<i>Falco tinnunculus</i>	0.6	0.62
	<i>Milvus migrans</i>	25.94	34.43
<b>Study design</b>	Site comparison. 40		
<b>Baseline Comparison</b>	No information on baseline. 0		
<b>Intra treatment variation</b>	No spatial replicates. No information on temporal variation. 0		
<b>Measurement of Co-interventions</b>	No information on management but vegetation cover was variable with the treatment site being open and the control having higher vegetation cover presumably as a result of differing management or management history. 0		
<b>Replication &amp; parameter of abundance</b>	Linear transects were walked with temporal replication. Bird species and number were recorded along with other unreported variables. 4		
<b>Attrition bias</b>	No losses to follow up. 2		
<b>Sum of Data quality</b>	46		
<b>Notes</b>	There are two potential control areas. The Np area was selected as the better of the two as it had a ridge of the same orientation as the wind farm site. Data on the abundance of passerine bird nests was presented in addition to the extracted data. This was included in qualitative outcomes but not meta-analysis to retain independence. The transect data was preferred as it contained a measure of range. This was converted to sd (Nb maximum Black Kite number per km is stated as 1111.12. It is assumed that the decimal point is in the wrong place and that this reads 111.1) The author was contacted to verify this, but did not respond to our enquiries. Data was extracted from table 1 p400, table 2 p401 with table 3 added to qualitative outcomes. Also information on White stork (more abundant in control).		

<b>Study</b>	Guillemette, M., Larsen, J.K. & Clausager, I. (1998) Impact assessment of an off-shore wind park on sea ducks. Neri Technical report no 227.		
<b>Methods</b>	Before and after site comparison based on bird counts.		
<b>Population and co-intervention</b>	Functional type of birds: Anseriformes. Location: Tunö knob, Denmark, offshore. Windfarm design: 10 turbines with an average output of 500kW per turbine. Habitat type: marine. Size of area: Wind farm observation area is 804ha (control 693ha) Area is defined as 0.8Km <sup>2</sup> . Site management techniques: unknown. Timescale: monitoring from 1994 to 1997. operation began in 1995. Timescale = 2 years as data was extracted from 1997 (longest time period).		
<b>Outcome (Abundance)</b>	Abundance of birds at Tunö knob and Ringebjerg sand control counted from observation towers during 3 years (n=19 treatment, n=15 control. the sd is presented in the figures).		

	Species	Treatment (windfarm)	Control
	<i>Somateria mollissima</i>	458	1958
	<i>Melanitta nigra</i>	7	0
Study design	Site comparison. 40		
Baseline Comparison	Abundance of eiders more equitable at baseline but still different (treatment, 1821 sd 1195, control 2134 sd 729), other factors equal. 4		
Intra treatment variation	No spatial replicates. Species numbers vary with time . 0		
Measurement of Co-interventions	No information on management but food availability (mussel abundance) varies with time. 0		
Replication & parameter of abundance	Bird count observations repeated in time. 4		
Attrition bias	No losses to follow up. 2		
Sum of Data quality	50		
Notes	This is a complex nested experimental design involving before, after, treatment, control site data at three spatial scales incorporating aerial and ground surveys and simultaneous / non simultaneous observations. Ground observations were selected as the least error prone data with mean, variance and sample size reported. The work is replicated by Guillemette, M., Larsen, J.K. & Clausager, I. (1997) Effekt af Tunø Knob vindmøllepark på fuglelivet Faglig rapport fra DMU nr 209. It is extended by Guillemette, M., Larsen, J.K. & Clausager, I. (1999) Assessing the impact of Tunø Knob wind park on sea ducks: the influence of food resources. Neri Technical report no 263. This body of literature together indicates that the windfarm may not be responsible for the sea duck decline as there is large natural temporal variation in sea duck abundance and the decline in sea ducks is accompanied by a decline in their food availability. Data was extracted from figure 7 p26, figure 19 p42.		

<b>Study</b>	Hunt, W. G., et al (1995). A pilot golden eagle population study in the Altamont Pass wind resource area, California. Santa Cruz, Predatory Bird Research Group, University of California.		
Methods	Site comparison based on bird counts.		
Population and co-intervention	Functional type of birds: Accipitriformes. Location: Altamont, California, inland. Windfarm design: 6500 turbines with an average output of 85kW per turbine (based on Altamont output of 548.32MW Wind project database). Habitat type: grassland. Size of area: 189Km <sup>2</sup> . Site management techniques: cattle grazing. Timescale: weekly monitoring from May to November 1994. operation began in 1982. Timescale = 12 years.		
Outcome (Abundance)	Mean number of eagles observed per Km <sup>2</sup> per road survey. (n=16 treatment, n=2 control)		
	Species	Treatment (windfarm)	Control
	<i>Aquila chrysaetos</i>	0.08	0.18
Study design	Site comparison. 40		
Baseline Comparison	No information on baseline. 0		
Intra treatment variation	Spatial replicates vary with respect to turbine number and design, habitat types and size. 2		
Measurement of Co-interventions	Ground squirrels are culled in windfarm area reducing prey abundance. 0		
Replication & parameter of abundance	16 roads were driven along weekly in the treatment area and two in the control area. Bird numbers were recorded along with other variables. 4		
Attrition bias	No losses to follow up. 2		
Sum of Data quality	48		
Notes	16 segments were identified in the wind resource area for ground survey. They were surveyed		

weekly from May to November. Site 300 was used as a control (two survey segments). Mean number of eagles per km<sup>2</sup> were read off a graph for each segment and an overall mean and sd calculated. The text provided means for the two control replicates. Data was extracted from figure 9.3 and text on p95. Also information on Red-tailed hawks but no control data was presented. Radio tagging and nest density data are also available. The work is replicated in Hunt et al. (1999) A population study of Golden Eagles in the Altamont Pass Wind Resource Area: Population trend analysis 1994-1997. NREL/SR 500-26092.

<b>Study</b>	Johnson, G. D., Erickson, W.P, Strickland, M.D., Shepherd, M.F. & Shepherd, D.A. (2000). Avian monitoring studies at the Buffalo Ridge Wind Resource Area, Minnesota: Results of a 4-year study. Technical Report prepared for Northern States Power Co., Minneapolis.																																																																																																																																																																																																	
<b>Methods</b>	BACI design monitoring of bird abundance (3 sites and one non independent control).																																																																																																																																																																																																	
<b>Population and co-intervention</b>	<p>Functional type of birds: Accipitriformes, Anseriformes, Charadriiformes, Falconiformes and Passeriformes.</p> <p>Location: Buffalo ridge, Minnesota, inland.</p> <p>Windfarm design: P1 73 turbines 342kW (25MW plant), P2 143 turbines 750kW (107.25MW plant), P3 138 turbines 750kW (103.5MW plant).</p> <p>Habitat type: arable.</p> <p>Size of area: P1 12.75Km<sup>2</sup>, P2 47Km<sup>2</sup>, P3 47Km<sup>2</sup> (P1, 8.5miles, P2/P3 25-38miles).</p> <p>Site management techniques: unknown.</p> <p>Timescale: monitoring from 1996 to 1999. operation began in 1994 P1, 1998 P2, 1999 P3.</p> <p>Timescale = 3yrs P1, 2yrs P2, 1yr P1.</p>																																																																																																																																																																																																	
<b>Outcome (Abundance)</b>	<p>Mean abundance of birds observed during point counts 15March-15November 1996-1999. (P1n= 32, P2n= 71, P3n= 25, controln= 29 (based on number of count sites averaged by 16 observations pa over 4 years).</p> <table border="1"> <thead> <tr> <th rowspan="2">Species</th> <th rowspan="2"></th> <th colspan="3">Treatment (windfarm)</th> <th rowspan="2">Control</th> </tr> <tr> <th>P1</th> <th>P2</th> <th>P3</th> </tr> </thead> <tbody> <tr><td><i>Mergus merganser</i></td><td>sp</td><td>0</td><td>0.01</td><td>0</td><td>0.01</td></tr> <tr><td><i>Anas platyrhynchos</i></td><td>sp</td><td>0.1</td><td>0.28</td><td>0.19</td><td>0.13</td></tr> <tr><td><i>Anas discors</i></td><td>sp</td><td>0.01</td><td>0.01</td><td>0.03</td><td>0.01</td></tr> <tr><td><i>Anas crecca</i></td><td>sp</td><td>0</td><td>0.01</td><td>0</td><td>0.01</td></tr> <tr><td><i>Aix sponsa</i></td><td>sp</td><td>0.01</td><td>0.02</td><td>0.01</td><td>0.01</td></tr> <tr><td><i>Branta canadensis</i></td><td>sp</td><td>0.11</td><td>0.06</td><td>0.18</td><td>0.25</td></tr> <tr><td><i>Anser caerulescens</i></td><td>sp</td><td>0</td><td>0.09</td><td>0</td><td>0.16</td></tr> <tr><td><i>Anser albifrons</i></td><td>sp</td><td>0</td><td>0</td><td>0</td><td>0.16</td></tr> <tr><td><i>Fulica americana</i></td><td>a</td><td>0</td><td>0</td><td>0</td><td>0.01</td></tr> <tr><td><i>Bartramia longicauda</i></td><td>s</td><td>0.01</td><td>0.02</td><td>0.05</td><td>0.06</td></tr> <tr><td><i>Pluvialis dominica</i></td><td>sp</td><td>0.02</td><td>0.03</td><td>0.14</td><td>0.15</td></tr> <tr><td><i>Charadrius vociferus</i></td><td>s</td><td>0.09</td><td>0.23</td><td>0.12</td><td>0.25</td></tr> <tr><td><i>Calidris melanotos</i></td><td>s</td><td>0</td><td>0</td><td>0.1</td><td>0.02</td></tr> <tr><td><i>Tringa melanoleuca</i></td><td>sp</td><td>0</td><td>0.02</td><td>0.01</td><td>0.01</td></tr> <tr><td><i>Gallinago gallinago</i></td><td>sp</td><td>0.01</td><td>0.01</td><td>0.03</td><td>0.03</td></tr> <tr><td><i>Circus cyaneus</i></td><td>sp</td><td>0.01</td><td>0.03</td><td>0.02</td><td>0.02</td></tr> <tr><td><i>Accipiter striatus</i></td><td>a</td><td>0</td><td>0.01</td><td>0.01</td><td>0.01</td></tr> <tr><td><i>Accipiter cooperii</i></td><td>s</td><td>0</td><td>0</td><td>0</td><td>0.01</td></tr> <tr><td><i>Buteo platypterus</i></td><td>sp</td><td>0.01</td><td>0.01</td><td>0</td><td>0.01</td></tr> <tr><td><i>Buteo jamaicensis</i></td><td>a</td><td>0.02</td><td>0.04</td><td>0.04</td><td>0.05</td></tr> <tr><td><i>Buteo swainsoni</i></td><td>a</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td></tr> <tr><td><i>Buteo lagopus</i></td><td>a</td><td>0</td><td>0.01</td><td>0</td><td>0.01</td></tr> <tr><td><i>Haliaeetus leucocephalus</i></td><td>a</td><td>0</td><td>0</td><td>0</td><td>0.01</td></tr> <tr><td><i>Falco columbarius</i></td><td>sp</td><td>0</td><td>0</td><td>0</td><td>0.01</td></tr> <tr><td><i>Falco sparverius</i></td><td>s</td><td>0.01</td><td>0.01</td><td>0.02</td><td>0.03</td></tr> <tr><td><i>Tyrannus tyrannus</i></td><td>s</td><td>0.01</td><td>0.06</td><td>0.07</td><td>0.16</td></tr> <tr><td><i>Tyrannus verticalis</i></td><td>s</td><td>0.01</td><td>0.02</td><td>0</td><td>0.02</td></tr> <tr><td><i>Sayornis phoebe</i></td><td>a</td><td>0</td><td>0</td><td>0</td><td>0.01</td></tr> <tr><td><i>Empidonax minimus</i></td><td>sp</td><td>0.01</td><td>0.01</td><td>0</td><td>0.01</td></tr> <tr><td><i>Eremophila alpestris</i></td><td>a</td><td>0.19</td><td>1.34</td><td>0.46</td><td>0.82</td></tr> </tbody> </table>					Species		Treatment (windfarm)			Control	P1	P2	P3	<i>Mergus merganser</i>	sp	0	0.01	0	0.01	<i>Anas platyrhynchos</i>	sp	0.1	0.28	0.19	0.13	<i>Anas discors</i>	sp	0.01	0.01	0.03	0.01	<i>Anas crecca</i>	sp	0	0.01	0	0.01	<i>Aix sponsa</i>	sp	0.01	0.02	0.01	0.01	<i>Branta canadensis</i>	sp	0.11	0.06	0.18	0.25	<i>Anser caerulescens</i>	sp	0	0.09	0	0.16	<i>Anser albifrons</i>	sp	0	0	0	0.16	<i>Fulica americana</i>	a	0	0	0	0.01	<i>Bartramia longicauda</i>	s	0.01	0.02	0.05	0.06	<i>Pluvialis dominica</i>	sp	0.02	0.03	0.14	0.15	<i>Charadrius vociferus</i>	s	0.09	0.23	0.12	0.25	<i>Calidris melanotos</i>	s	0	0	0.1	0.02	<i>Tringa melanoleuca</i>	sp	0	0.02	0.01	0.01	<i>Gallinago gallinago</i>	sp	0.01	0.01	0.03	0.03	<i>Circus cyaneus</i>	sp	0.01	0.03	0.02	0.02	<i>Accipiter striatus</i>	a	0	0.01	0.01	0.01	<i>Accipiter cooperii</i>	s	0	0	0	0.01	<i>Buteo platypterus</i>	sp	0.01	0.01	0	0.01	<i>Buteo jamaicensis</i>	a	0.02	0.04	0.04	0.05	<i>Buteo swainsoni</i>	a	0.01	0.01	0.01	0.01	<i>Buteo lagopus</i>	a	0	0.01	0	0.01	<i>Haliaeetus leucocephalus</i>	a	0	0	0	0.01	<i>Falco columbarius</i>	sp	0	0	0	0.01	<i>Falco sparverius</i>	s	0.01	0.01	0.02	0.03	<i>Tyrannus tyrannus</i>	s	0.01	0.06	0.07	0.16	<i>Tyrannus verticalis</i>	s	0.01	0.02	0	0.02	<i>Sayornis phoebe</i>	a	0	0	0	0.01	<i>Empidonax minimus</i>	sp	0.01	0.01	0	0.01	<i>Eremophila alpestris</i>	a	0.19	1.34	0.46	0.82
Species		Treatment (windfarm)			Control																																																																																																																																																																																													
		P1	P2	P3																																																																																																																																																																																														
<i>Mergus merganser</i>	sp	0	0.01	0	0.01																																																																																																																																																																																													
<i>Anas platyrhynchos</i>	sp	0.1	0.28	0.19	0.13																																																																																																																																																																																													
<i>Anas discors</i>	sp	0.01	0.01	0.03	0.01																																																																																																																																																																																													
<i>Anas crecca</i>	sp	0	0.01	0	0.01																																																																																																																																																																																													
<i>Aix sponsa</i>	sp	0.01	0.02	0.01	0.01																																																																																																																																																																																													
<i>Branta canadensis</i>	sp	0.11	0.06	0.18	0.25																																																																																																																																																																																													
<i>Anser caerulescens</i>	sp	0	0.09	0	0.16																																																																																																																																																																																													
<i>Anser albifrons</i>	sp	0	0	0	0.16																																																																																																																																																																																													
<i>Fulica americana</i>	a	0	0	0	0.01																																																																																																																																																																																													
<i>Bartramia longicauda</i>	s	0.01	0.02	0.05	0.06																																																																																																																																																																																													
<i>Pluvialis dominica</i>	sp	0.02	0.03	0.14	0.15																																																																																																																																																																																													
<i>Charadrius vociferus</i>	s	0.09	0.23	0.12	0.25																																																																																																																																																																																													
<i>Calidris melanotos</i>	s	0	0	0.1	0.02																																																																																																																																																																																													
<i>Tringa melanoleuca</i>	sp	0	0.02	0.01	0.01																																																																																																																																																																																													
<i>Gallinago gallinago</i>	sp	0.01	0.01	0.03	0.03																																																																																																																																																																																													
<i>Circus cyaneus</i>	sp	0.01	0.03	0.02	0.02																																																																																																																																																																																													
<i>Accipiter striatus</i>	a	0	0.01	0.01	0.01																																																																																																																																																																																													
<i>Accipiter cooperii</i>	s	0	0	0	0.01																																																																																																																																																																																													
<i>Buteo platypterus</i>	sp	0.01	0.01	0	0.01																																																																																																																																																																																													
<i>Buteo jamaicensis</i>	a	0.02	0.04	0.04	0.05																																																																																																																																																																																													
<i>Buteo swainsoni</i>	a	0.01	0.01	0.01	0.01																																																																																																																																																																																													
<i>Buteo lagopus</i>	a	0	0.01	0	0.01																																																																																																																																																																																													
<i>Haliaeetus leucocephalus</i>	a	0	0	0	0.01																																																																																																																																																																																													
<i>Falco columbarius</i>	sp	0	0	0	0.01																																																																																																																																																																																													
<i>Falco sparverius</i>	s	0.01	0.01	0.02	0.03																																																																																																																																																																																													
<i>Tyrannus tyrannus</i>	s	0.01	0.06	0.07	0.16																																																																																																																																																																																													
<i>Tyrannus verticalis</i>	s	0.01	0.02	0	0.02																																																																																																																																																																																													
<i>Sayornis phoebe</i>	a	0	0	0	0.01																																																																																																																																																																																													
<i>Empidonax minimus</i>	sp	0.01	0.01	0	0.01																																																																																																																																																																																													
<i>Eremophila alpestris</i>	a	0.19	1.34	0.46	0.82																																																																																																																																																																																													

<i>Anthus rubescens</i>	a	0.02	0.02	0.05	0.01
<i>Cyanocitta cristata</i>	a	0.04	0.05	0.21	0.25
<i>Corvus brachyrhynchos</i>	a	0.1	0.16	0.23	0.11
<i>Sitta carolinensis</i>	sp	0	0	0	0.01
<i>Sturnus vulgaris</i>	a	1.55	0.67	1.15	0.88
<i>Piranga olivacea</i>	sp	0	0	0	0.01
<i>Dolichonyx oryzivorus</i>	s	0.17	0.29	0.23	0.2
<i>Molothrus ater</i>	sp	0.31	0.32	0.33	0.69
<i>Xanthocephalus xanthocephalus</i>	sp	0.03	0.06	0.01	0.02
<i>Agelaius phoeniceus</i>	sp	0.72	1.31	0.80	1.16
<i>Euphagus carolinus</i>	a	0	0.01	0	0.03
<i>Euphagus cyanocephalus</i>	a	0.01	0.01	0.01	0.04
<i>Sturnella neglecta</i>	sp	0.13	0.29	0.29	0.35
<i>Icterus spurius</i>	s	0	0	0.01	0.01
<i>Icterus galbula</i>	sp	0.01	0.01	0	0.01
<i>Quiscalus quiscula</i>	s	0.29	0.22	0.53	0.44
<i>Carpodacus mexicanus</i>	sp	0.01	0	0.01	0.01
<i>Carduelis tristis</i>	s	0.1	0.16	0.21	0.24
<i>Carduelis pinus</i>	a	0	0.01	0	0.02
<i>Carduelis flammea</i>	sp	0	0.05	0	0.1
<i>Calcarius lapponicus</i>	sp	0.15	0.77	0.73	1.42
<i>Poocetes gramineus</i>	a	0.06	0.11	0.07	0.24
<i>Passerculus sandwichensis</i>	s	0.08	0.29	0.3	0.18
<i>Ammodramus savannarum</i>	s	0.03	0.19	0.14	0.07
<i>Zonotrichia querula</i>	a	0.01	0.02	0.01	0.09
<i>Zonotrichia albicollis</i>	a	0.01	0.01	0.01	0.02
<i>Spizella arborea</i>	a	0.03	0.07	0.02	0.13
<i>Spizella passerina</i>	s	0.01	0.01	0.02	0.01
<i>Spizella pallida</i>	s	0.03	0.1	0.01	0.05
<i>Melospiza georgiana</i>	a	0	0.01	0.01	0.01
<i>Chondestes grammacus</i>	s	0	0	0	0.01
<i>Junco hyemalis</i>	a	0.02	0.03	0.04	0.09
<i>Melospiza melodia</i>	s	0.08	0.11	0.15	0.21
<i>Melospiza lincolni</i>	a	0.01	0.01	0.03	0.03
<i>Zonotrichia leucophrys</i>	sp	0	0	0.01	0.01
<i>Spiza americana</i>	s	0.14	0.1	0.18	0.09
<i>Pheucticus ludovicianus</i>	sp	0	0.01	0	0.01
<i>Guiraca caerulea</i>	s	0	0.01	0	0.01
<i>Petrochelidon pyrrhonota</i>	s	0.01	0.14	0.26	0.44
<i>Stelgidopteryx serripennis</i>	s	0	0.01	0.01	0.01
<i>Hirundo rustica</i>	s	0.59	0.78	0.87	0.79
<i>Tachycineta bicolor</i>	sp	0.04	0.06	0.04	0.09
<i>Riparia riparia</i>	a	0	0.02	0	0.02
<i>Vireo gilvus</i>	sp	0.01	0.01	0	0.01
<i>Vireo olivaceus</i>	sp	0	0.01	0	0.01
<i>Setophaga ruticilla</i>	sp	0.01	0.01	0	0.01
<i>Dendroica virens</i>	sp	0	0	0	0.01
<i>Wilsonia canadensis</i>	sp	0	0	0	0.01
<i>Oporornis agilis</i>	sp	0	0	0	0.01
<i>Geothlypis trichas</i>	s	0.13	0.09	0.13	0.08
<i>Vermivora peregrina</i>	sp	0.01	0.01	0	0.01

	<i>Dendroica palmarum</i>	sp	0	0	0.01	0.01
	<i>Dendroica petechia</i>	sp	0.01	0.01	0	0.02
	<i>Dendroica coronata</i>	sp	0	0.01	0.01	0.02
	<i>Passer domesticus</i>	a	0.04	0.1	0.11	0.12
	<i>Dumetella carolinensis</i>	s	0.01	0.01	0.01	0.01
	<i>Toxostoma rufum</i>	s	0.01	0.01	0.02	0.02
	<i>Troglodytes aedon</i>	s	0.01	0.03	0.06	0.08
	<i>Cistothorus platensis</i>	s	0.17	0.12	0.1	0.03
	<i>Regulus calendula</i>	sp	0	0.01	0.01	0.01
	<i>Poecile atricapilla</i>	a	0.01	0.01	0.01	0.03
	<i>Catharus guttatus</i>	sp	0.01	0	0	0.01
	<i>Catharus minimus</i>	sp	0	0	0	0.01
	<i>Turdus migratorius</i>	a	0.15	0.18	0.15	0.24
	<i>Sialia sialis</i>	a	0.01	0.02	0	0.06
	<i>Lanius excubitor</i>	a	0.01	0	0	0.01
Study design	Site comparison. 40					
Baseline Comparison	Abundance variable but other factors equal at baseline:4					
Intra treatment variation	No information on spatial or temporal variation (species vary with time). 0					
Measurement of Co-interventions	No information on management. 0					
Replication & parameter of abundance	Bird counts replicated in space and time: 4					
Attrition bias	No losses to follow up. 2					
Sum of Data quality	50					
Notes	<p>Data was extracted from three windfarm sites and one non independent reference area. Maximum mean abundance of each species (based on the control) was extracted thus summer abundance was extracted for summer residents, spring or fall was extracted for winter residents scarce in summer (s=summer, sp= spring, a=autumn). Additional data was available on non relevant species and relevant species that had no control data. Before-after data was not utilised although effect sizes are presented in tables 15 and 16 and the raw data in figures. The author was contacted in an attempt to obtain variance and verify sample size information but did not have the resources to help with our enquiries. Data was extracted from Appendix B p160-180. Other work on the site has been excluded from meta-analysis to retain independence but included in qualitative outcomes (Leddy, K. L., Higgins, K. F. &amp; Naugle, D. E. (1999) Effects of wind turbines on upland nesting birds in Conservation Reserve Program grasslands. <i>Wilson Bulletin</i> <b>111</b>(1): 100-104.). It should be noted that the site comparison is based on a mean from all years of monitoring thus treatment sites do not have windfarms present throughout. Thus this data down weights the impact of windfarms.</p>					

<b>Study</b>	Johnson, G. D., Young Jr., J.P., Derby, C.E., Erickson, W.P, Strickland, M.D. & Kern, J.W. (2000). <i>Wildlife Monitoring Studies, SeaWest Windpower Plant, Carbon County, Wyoming: 1995 - 1999. Cheyenne, Wyoming, WEST.</i>
Methods	Bird counts replicated 3 times between 15May and 31July on 8 transects with 5 points per transect (n=40).
Population and co-intervention	<p>Functional type of birds: Accipitriformes, Anseriformes, Charadriiformes, Falconiformes and Passeriformes.</p> <p>Location: Foot creek rim, Carbon County, Wyoming, inland.</p> <p>Windfarm design: 105 turbines with an average output of 647kW per turbine.</p> <p>Habitat type: cottonwood, aspen and rock outcrops mentioned in text. Scrub/woodland?</p> <p>Size of area: Simpsons Ridge and Foot creek rim are 24550ha /2 = FCR?. Area is defined as 122.75Km<sup>2</sup>.</p> <p>Site management techniques: unknown.</p> <p>Timescale: monitoring from 1995 to 1999. operation began in 1999. Timescale = 1 years.</p>
Outcome	Mean number of birds observed per 8 minute count (no variance measure) (n=40)

(Abundance)	Species	Treatment (windfarm)	Control
	<i>Branta canadensis</i>	0.054	0
	<i>Anas platyrhynchos</i>	0.01	0
	<i>Cathartes aura</i>	0.005	0
	<i>Accipiter striatus</i>	0.005	0
	<i>Buteo jamaicensis</i>	0.023	0
	<i>Buteo swainsoni</i>	0.005	0
	<i>Buteo regalis</i>	0.005	0.015
	<i>Circus cyaneus</i>	0.013	0
	<i>Aquila chrysaetos</i>	0.013	0.005
	<i>Falco mexicanus</i>	0.006	0.005
	<i>Falco sparverius</i>	0.017	0.01
	<i>Charadrius vociferus</i>	0.013	0.063
	<i>Gallinago gallinago</i>	0.006	0
	<i>Charadrius montanus</i>	0.058	0.038
	<i>Numenius americanus</i>	0	0.005
	<i>Phalaropus tricolor</i>	0.005	0
	<i>Tyrannus tyrannus</i>	0.005	0
	<i>Tyrannus verticalis</i>	0.005	0.005
	<i>Sayornis saya</i>	0	0.005
	<i>Contopus cooperi</i>	0.005	0
	<i>Empidonax occidentalis</i>	0.005	0
	<i>Contopus sordidulus</i>	0.027	0
	<i>Empidonax oberholseri</i>	0.005	0
	<i>Eremophila alpestris</i>	2.077	3.569
	<i>Tachycineta bicolor</i>	0.042	0
	<i>Hirundo rustica</i>	0.015	0.027
	<i>Petrochelidon pyrrhonota</i>	0.410	0.329
	<i>Stelgidopteryx serripennis</i>	0	0.006
	<i>Riparia riparia</i>	0.005	0.005
	<i>Tachycineta thalassina</i>	0.035	0.025
	<i>Corvus corax</i>	0.008	0.005
	<i>Pica hudsonia</i>	0.031	0
	<i>Cyanocitta cristata</i>	0.005	0
	<i>Troglodytes aedon</i>	0.1	0
	<i>Salpinctes obsoletus</i>	0.015	0.094
	<i>Oreoscoptes montanus</i>	0.035	0.142
	<i>Catharus ustulatus</i>	0.006	0
	<i>Dumetella carolinensis</i>	0.005	0
	<i>Turdus migratorius</i>	0.148	0.019
	<i>Sialia currucoides</i>	0.096	0.048
	<i>Catharus guttatus</i>	0.005	0
	<i>Sturnus vulgaris</i>	0.019	0
	<i>Vireo gilvus</i>	0.017	0
	<i>Regulus calendula</i>	0.005	0
	<i>Vermivora celata</i>	0.006	0
	<i>Dendroica petechia</i>	0.044	0
	<i>Dendroica coronata</i>	0.029	0
	<i>Oporornis tolmiei</i>	0.017	0
	<i>Sturnella neglecta</i>	0.075	0.442
	<i>Agelaius phoeniceus</i>	0.008	0.038
	<i>Euphagus cyanocephalus</i>	0.385	0.217
	<i>Quiscalus quiscula</i>	0.013	0
	<i>Molothrus ater</i>	0.052	0.027
	<i>Carduelis tristis</i>	0.115	0.005
	<i>Carduelis pinus</i>	0.165	0.005
	<i>Coccothraustes vespertinus</i>	0.005	0

	<i>Pipilo chlorurus</i>	0.248	0.027
	<i>Calcarius mccownii</i>	0	0.271
	<i>Passerculus sandwichensis</i>	0.013	0.015
	<i>Melospiza melodia</i>	0.015	0.005
	<i>Melospiza lincolnii</i>	0.005	0
	<i>Zonotrichia leucophrys</i>	0.017	0
	<i>Chondestes grammacus</i>	0	0.005
	<i>Ammodramus bairdii</i>	0.005	0
	<i>Pooecetes gramineus</i>	0.927	1.271
	<i>Spizella breweri</i>	0.448	0.771
	<i>Spizella passerina</i>	0.106	0
	<i>Junco hyemalis</i>	0.005	0
	<i>Calamospiza melanocorys</i>	0.01	0.019
	<i>Bombycilla cedrorum</i>	0.008	0
	<i>Poecile atricapilla</i>	0.005	0
Study design	Site comparison. 40		
Baseline Comparison	Abundance variable, size of areas and habitat type insufficiently reported:2		
Intra treatment variation	No information on spatial or temporal variation (species vary with time). 0		
Measurement of Co-interventions	No information on management. 0		
Replication & parameter of abundance	Bird counts replicated in space and time: 4		
Attrition bias	No losses to follow up. 2		
Sum of Data quality	48		
Notes	The author was contacted in an attempt to obtain variance and verify sample size information but did not have the resources to help with our enquiries. It should be noted that the site comparison is based on a mean from all years of monitoring thus treatment sites do not have windfarms present throughout. Thus this data down weights the impact of windfarms. Data was extracted from Appendix F p158-160.		

<b>Study</b>	Kerlinger, P. (2002). An Assessment of the Impacts of Green Mountain Power Corporation's Wind Power Facility on Breeding and Migrating Birds in Searsburg, Vermont. Golden, Colorado, National Renewable Energy Laboratory.		
Methods	Replicated bird counts before and after windfarm construction.		
Population and co-intervention	Functional type of birds: Accipitriformes, Falconiformes and Passeriformes. Location: Searsburg, Vermont, inland. Windfarm design: 11 turbines with an output of 550kW per turbine. Habitat type: North American hardwood Forest. Size of area: Wind farm area is 5ha. Area is defined as 0.05Km <sup>2</sup> . Site management techniques: unknown. Timescale: monitoring in1994 prior to windfarm construction and 1997 after operation. Operation began in 1996. Timescale = 1 year.		
Outcome (Abundance)	Breeding bird survey: mean number of birds observed or heard at point counts (n=21). Raptor data is based on counts but the methods are not described (n=21?)		
	Species	Treatment (1994)	Control (1997)
	<i>Corvus brachyrhynchos</i>	3	0
	<i>Carduelis tristis</i>	0	0.5
	<i>Setophaga ruticilla</i>	3	3
	<i>Turdus migratorius</i>	2	5
	<i>Icterus galbula</i>	1	0
	<i>Mniotilta varia</i>	5	3
	<i>Poecile atricapilla</i>	2	4
	<i>Dendroica fusca</i>	3	3
<i>Dendroica striata</i>	12	13	

<i>Dendroica caerulescens</i>	17	8
<i>Dendroica virens</i>	9	8
<i>Cyanocitta cristata</i>	1	3
<i>Certhia americana</i>	0	1
<i>Molothrus ater</i>	1	1
<i>Wilsonia canadensis</i>	15	6
<i>Bombycilla cedrorum</i>	1	0.5
<i>Chaetura pelagica</i>	1	0
<i>Spizella passerina</i>	0	1
<i>Geothlypis trichas</i>	1	0.5
<i>Dendroica pensylvanica</i>	3	3
<i>Picoides pubescens</i>	0	0.5
<i>Catharus minimus</i>	1	0.5
<i>Regulus satrapa</i>	1	0.5
<i>Picoides villosus</i>	0	0.5
<i>Catharus guttatus</i>	7	9
<i>Dendroica magnolia</i>	11	11
<i>Seiurus aurocapillus</i>	21	6
<i>Dryocopus pileatus</i>	0	0.5
<i>Carpodacus purpureus</i>	4	5
<i>Vireo olivaceus</i>	17	6
<i>Sitta canadensis</i>	2	2
<i>Agelaius phoeniceus</i>	0	0.5
<i>Pheucticus ludovicianus</i>	1	0.5
<i>Piranga olivacea</i>	1	0
<i>Junco hyemalis</i>	25	29
<i>Vireo solitarius</i>	3	0.5
<i>Catharus ustulatus</i>	24	4
<i>Troglodytes troglodytes</i>	6	3
<i>Zonotrichia albicollis</i>	22	14
<i>Sphyrapicus varius</i>	0	0.5
<i>Dendroica coronata</i>	15	32
<i>Cathartes aura</i>	8	3
<i>Pandion haliaetus</i>	13	6
<i>Circus cyaneus</i>	10	0
<i>Haliaeetus leucocephalus</i>	3	0
<i>Accipiter striatus</i>	121	6
<i>Accipiter cooperii</i>	9	6
<i>Accipiter gentilis</i>	1	0
<i>Buteo lineatus</i>	2	0
<i>Buteo platypterus</i>	96	6
<i>Buteo jamaicensis</i>	173	15
<i>Falco sparverius</i>	33	0
<i>Falco columbarius</i>	3	0
<i>Falco peregrinus</i>	1	0
Study design	Time series. 30	
Baseline Comparison	All factors equal at baseline. 6	
Intra treatment variation	No information on spatial variation. 0	
Measurement of Co-interventions	No information on management. 0	
Replication & parameter of abundance	Spatial replication (n=21) before and after construction. Bird species and number were recorded. 4	
Attrition bias	No losses to follow up. 2	

Sum of Data quality	42
Notes	The author was contacted in an attempt to obtain variance and verify sample size information but did not respond to our enquiries. Species seen or heard but not on the two official count days were given an abundance of 0.5. Data was extracted from table 4.3 p32-34 and table 6.2 p57. Also information on Ruffed grouse (more abundant prior to windfarm construction).

<b>Study</b>	Ketzenberg, C., Exo, K.M., Reichenbach, M., & Castor, M. (2002). Einfluss von Windkraftanlagen auf brütende Wiesenvögel. <i>Natur und Landschaft</i> <b>77</b> : 144-153. (translated by Ulrike Lange)								
Methods	Time series based on before and after data in 4 independent data sets A,B,C,D.								
Population and co-intervention	Functional type of birds: Charadriiformes. Location: all in lower Saxony (Germany), coastal. Windfarm design: Ahndeich, Georgshof, Leer: 14-19 turbines of 500-600kW. Bassens 34 turbines 500-600kW. Habitat type: maize, winter crops and grassland. Size of area: Ahndeich 7.47km <sup>2</sup> , Bassens 7.35 km <sup>2</sup> , Georgshof 1.38 km <sup>2</sup> , Leer 0.74 km <sup>2</sup> . Site management techniques: unknown. Timescale: 4 years								
Outcome (Abundance)	Mean breeding pair density per 10ha up to 1000m from windfarm before and after installation								
		Ahndeich		Bassens		Georgshof		Leer	
	Species	Treatm ent	control	Treatm ent	control	Treatm ent	control	Treatm ent	control
	<i>Haematopus ostralegus</i>	0.27	0.27	0.12	0.08	0.22	0	0.34	0.2
	<i>Vanellus vanellus</i>	1.17	1.46	0.34	0.19	1.23	1.01	0.90	1.66
	<i>Tringa totanus</i>	0.20	0.09	0.07	0.05	0	0.14	0.09	0.17
	<i>Limosa limosa</i>	0.35	0.51	0.12	0	-	-	0.26	0.26
Study design	Time series: 30								
Baseline Comparison	All factors equal at baseline: 6								
Intra treatment variation	No information on spatial variation. 0								
Measurement of Co-interventions	Changes in land use and variation in methodology: 0								
Replication & parameter of abundance	Well replicated observations using objective parameter of abundance: 4								
Attrition bias	No losses to follow up: 2								
Sum of Data quality	42								
Notes	Some density data exists for <i>Alauda arvensis</i> after windfarm construction but there is no data prior to windfarm construction therefore it was not extracted. Data was extracted from table 1, p145. The author was contacted in an attempt to obtain variance and sample size information but did not respond to our enquiries.								

<b>Study</b>	Larsson, A. K. (1994). The Environmental Impact from an Offshore Plant. <i>Wind Engineering</i> <b>18</b> : 213–218.								
Methods	BACI data with before (March to June 1990) and after (March to June 1991) counts of bird number replicated on 16 and 12 occasions respectively at 3 control and 3 treatment sites (one turbine).								
Population and co-intervention	Functional type of birds: Anseriformes. Location: Sweden, Offshore. Windfarm design: 1 220kW turbine. Habitat type: maritime. Size of area: 1km <sup>2</sup> . Site management techniques: unknown. Timescale: 1 year after first operation.								

Outcome (Abundance)	Mean count of bird number (n=3, sd based on the three replicates in treatment and control)		
		Treatment	Control
	<i>Cygnus olor</i>	0.8	3.4
	<i>Tadorna tadorna</i>	1.6	2.6
	<i>Anas platyrhynchos</i>	1.7	3.4
	<i>Somateria mollissima</i>	0.3	8.4
	<i>Clangula hyemalis</i>	10.2	21.6
	<i>Mergus serrator</i>	0.8	3.9
Study design	Site comparison: 40		
Baseline Comparison	Control and treatment sites similar at baseline with respect to abundance, functional type, location habitat and size of area: 6		
Intra treatment variation	Replicates comparable and equal with respect to all specified factors:5		
Measurement of Co-interventions	Site management unreported: 0		
Replication & parameter of abundance	Well replicated objective parameters of abundance: 4		
Attrition bias	No losses to follow up: 2		
Sum of Data quality	57		
Notes	Data extracted from Figure 2, p216. The author was contacted in an attempt to obtain more detailed variance information (the 3 replicates were monitored repeatedly, which could theoretically increase sample size) but did not respond to our enquiries.		

<b>Study</b>	Meek, E. R., Ribbands, J.B., Christer, W.G., Davey, P.R. & Higginson, I. (1993). The effects of aero-generators on moorland bird populations in the Orkney Islands, Scotland. <i>Bird Study</i> <b>40</b> : 140-143.			
Methods	Site comparison			
Population and co-intervention	Functional type of birds: Anseriformes, Charadriiformes and Passeriformes. Location: Orkney, Scotland, inland. Windfarm design: 2 turbines 275kW. (a third turbine was constructed in 1987). Habitat type: bog heath grass (experimental) wet and dry heath (control) Size of area: 50ha (control, 56 for treatment) i.e. 0.5km <sup>2</sup> . Site management techniques: burning, rabbit and vole grazing (treatment) peat extraction, burning and sheep grazing (control). Timescale: 1981-1989 for monitoring, operation began 1983. Timescale= 6 years			
Outcome (Abundance)	Mean no pairs per year (n=9, se presented)		Treatment (burgar hill)	Control (sleet moss)
	Anseriformes (mainly <i>Anas Penelope</i> , <i>Anas crecca</i> , <i>Anas platyrhynchos</i> )		9.2 (se 3.6)	4.6 (se 4.5)
	Charadriiformes ( <i>Calidris alpina</i> , <i>Pluvialis apricaria</i> )		25 (se 2)	15.7 (se 2.4)
	Passeriformes ( <i>Alauda arvensis</i> , <i>Oenanthe oenanthe</i> , <i>Saxicola torquata</i> , <i>Carduelis flavirostris</i> )		25.4 (se 2.4)	50.1 (se 1.5)
Study design	Site comparison: 40			
Baseline Comparison	Heterogeneity with respect to species abundance, type and habitat. Location and size similar: 2			
Intra treatment variation	No information on spatial variation within replicates : 0			
Measurement of Co-interventions	Site management not equal: 0			
Replication & parameter of abundance	Well replicated objective parameter of abundance used within treatment and control: 4			
Attrition bias	No losses to follow up: 2			
Sum of Data quality	48			
Notes	Cites uncaptured reference as containing abundance data: Winkelman, J.E. (1990) Verstorning			

van vogels door de Sepproofwindcentrale te Oosterbierum (Fr.) tijdens bouwfase en half-operationele situaties (1984-1989). Rin-rapport 90/9. Rijksinstituut voor Natuur-beheer, Arnhem. Also contains abundance data for gulls, red grouse, and red-throated diver. It should be noted that the site comparison is based on a mean from all years of monitoring thus the treatment site does not have wind turbines present throughout.

<b>Study</b>	Phillips, J. F. (1994). <i>The effects of a windfarm on the upland breeding bird communities of Bryn Titli, mid-Wales: 1993-1994</i> . Newtown, RSPB.		
<b>Methods</b>	Numbers of breeding birds surveyed using standard BTO transect methodology in area of windfarm and adjacent areas as a control. Baseline data was collected prior to the construction of the windfarm.		
<b>Population and co-intervention</b>	Functional type of birds: Accipitriformes, Anseriformes, Falconiformes & Passeriformes. Location: Wales, inland Windfarm design: 22 turbines of 450kW. Habitat type: Moorland fringe ranging from low lying farmland along the river Wye to woodland (W10/11), U20, improved pastures (MG5/6?) grass moor (U5?) and <i>Calluna</i> dominated moorland (H10/12?). Size of area: Windfarm area 6 km <sup>2</sup> (control area is adjacent 8 km <sup>2</sup> ). Site management techniques: The turbines are located on sheep walk (U5?). Timescale: 1 year since operation.		
<b>Outcome (Abundance)</b>	Mean no of pairs per Km <sup>2</sup> (ntreatment=6, ncontrol=8).	Treatment (wf 94)	Control (94)
	<i>Anas platyrhynchos</i>	0	0.25
	<i>Buteo buteo</i>	0.5	0.875
	<i>Falco tinnunculus</i>	0	0.125
	<i>Falco peregrinus</i>	0.16666667	0
	<i>Turdus merula</i>	2	1.625
	<i>Sylvia atricapilla</i>	0.33333333	0.25
	<i>Parus caeruleus</i>	1.33333333	1.125
	<i>Pyrrhula pyrrhula</i>	0	0.625
	<i>Corvus corone</i>	0.33333333	0.5
	<i>Fringilla coelebs</i>	7.66666667	6.875
	<i>Parus ater</i>	0.16666667	0.625
	<i>Prunella modularis</i>	0.33333333	0.625
	<i>Sylvia borin</i>	1	0.125
	<i>Regulus regulus</i>	0.66666667	1
	<i>Carduelis carduelis</i>	0.33333333	0.25
	<i>Parus major</i>	1.16666667	0.5
	<i>Carduelis chloris</i>	0	0
	<i>Motacilla cinerea</i>	0.16666667	0.125
	<i>Passer domesticus</i>	0.33333333	0
	<i>Corvus monedula</i>	0.16666667	0.25
	<i>Garrulus glandarius</i>	0.16666667	0.125
	<i>Carduelis cannabina</i>	1.5	3.25
	<i>Aegithalos caudatus</i>	0.16666667	0.125
	<i>Pica pica</i>	0.66666667	0.625
	<i>Parus palustris</i>	0	0.125
	<i>Anthus pratensis</i>	35.66666667	44.75
	<i>Turdus viscivorus</i>	0.33333333	0.25
	<i>Oenanthe oenanthe</i>	1.16666667	1.5
	<i>Sitta europaea</i>	0	0.125
	<i>Ficedula hypoleuca</i>	0.5	1.125
	<i>Motacilla alba</i>	1	1
	<i>Corvus corax</i>	0.5	0
	<i>Carduelis flammea</i>	1	1
	<i>Phoenicurus phoenicurus</i>	3.33333333	2
	<i>Emberiza schoeniclus</i>	0.16666667	0.125

	<i>Erithacus rubecula</i>	5.33333333	2.5
	<i>Corvus frugilegus</i>	0	0
	<i>Carduelis spinus</i>	0	0.5
	<i>Alauda arvensis</i>	15.16666667	14.875
	<i>Turdus philomelos</i>	1.5	0.75
	<i>Muscicapa striata</i>	1	0.5
	<i>Sturnus vulgaris</i>	0	0.125
	<i>Saxicola torquata</i>	0.33333333	0
	<i>Hirundo rustica</i>	0.16666667	0.125
	<i>Certhia familiaris</i>	0.16666667	0.25
	<i>Anthus trivialis</i>	1.66666667	1.375
	<i>Saxicola rubetra</i>	3.66666667	5.375
	<i>Sylvia communis</i>	0	0.125
	<i>Parus montanus</i>	0.16666667	0
	<i>Phylloscopus trochilus</i>	6.83333333	6.125
	<i>Phylloscopus sibilatrix</i>	0.16666667	0.25
	<i>Troglodytes troglodytes</i>	5.16666667	4.75
	<i>Emberiza citrinella</i>	0.83333333	0.125
Study design	Site comparison: 40		
Baseline Comparison	Some heterogeneity as regards functional type and habitat (control contains more moorland fringe than treatment). Other than that baseline is similar for treatment and control particularly abundance of species (tested with Mann-Whitney test by authors of report): 4		
Intra treatment variation	Transects were replicated but we are using km <sup>2</sup> as a unit of replication as reported in the manuscript. Some unbalanced heterogeneity with respect to species: 4		
Measurement of Co-interventions	Habitat not equal in treatment and control thus land management not equal: 0		
Replication & parameter of abundance	Well replicated parameter of abundance using accepted technique: 4		
Attrition bias	No losses to follow up: 2		
Sum of Data quality	54		
Notes	Replication based on Km <sup>2</sup> as reported in the manuscript. Additional data in Green, M. (1994). Effects of windfarm construction on the winter bird community of the Bryn Titli uplands: 1993/94. Newtown, RSPB and Green, M. (1995). Effects of windfarm operation on the winter bird community of the Bryn Titli Uplands: 1994/95. Newtown, RSPB but Green states that this is not comparable. Data is also presented on Tawny owls.		

<b>Study</b>	Schmidt, E. P., Bock, C. E.; Armstrong, D. M. (2003). National Wind Technology Center Site Environmental Assessment: Bird and Bat Use and Fatalities -- Final Report; Period of Performance: April 23, 2001 -- December 31, 2002. .		
Methods	Bird counts replicated in space and time in treatment and control sites.		
Population and co-intervention	Functional type of birds: Accipitriformes, Anseriformes, Falconiformes and Passeriformes. Location: Jefferson County, Colorado, inland Windfarm design: Turbine power and number unknown. Habitat type: grassland with some <i>Pinus ponderosa</i> . Size of area: unknown. Site management techniques: ungrazed. Timescale: monitoring from 2001 to 2002. Not known when operation began.		
Outcome (Abundance)	Mean abundance per count (treatmentn=6, controln=12, se presented).		
	Species	Treatment (windfarm)	Control
	<i>Branta canadensis</i>	0	0.004
	<i>Anas platyrhynchos</i>	0.013	0
	<i>Cathartes aura</i>	0.013	0.016
	<i>Circus cyaneus</i>	0.027	0.027
	<i>Aquila chrysaetos</i>	0.004	0.011
	<i>Haliaeetus leucocephalus</i>	0	0.007
	<i>Buteo jamaicensis</i>	0.062	0.069

<i>Buteo lagopus</i>	0.004	0.013
<i>Buteo regalis</i>	0.004	0.016
<i>Falco sparverius</i>	0.160	0.078
<i>Falco mexicanus</i>	0.004	0.002
<i>Falco peregrinus</i>	0.004	0
<i>Sayornis saya</i>	0.031	0.011
<i>Tyrannus verticalis</i>	0	0.004
<i>Pica hudsonia</i>	0.053	0.049
<i>Corvus corax</i>	0.013	0.076
<i>Eremophila alpestris</i>	0.022	0.360
<i>Petrochelidon pyrrhonota</i>	0.018	0.142
<i>Hirundo rustica</i>	0.009	0.042
<i>Sialia currucoides</i>	0	0.022
<i>Turdus migratorius</i>	0	0.002
<i>Sturnus vulgaris</i>	0.067	0.027
<i>Pipilo chlorurus</i>	0.004	0
<i>Pipilo maculatus</i>	0	0.002
<i>Spizella passerina</i>	0	0.002
<i>Chondestes grammacus</i>	0	0.04
<i>Ammodramus savannarum</i>	0.04	0.06
<i>Calamospiza melanocorys</i>	0	0.002
<i>Passerculus sandwichensis</i>	0	0.002
<i>Poocetes gramineus</i>	0.751	1.022
<i>Guiraca caerulea</i>	0	0.002
<i>Sturnella neglecta</i>	0.853	0.776
<i>Agelaius phoeniceus</i>	0.004	0.042
<i>Quiscalus quiscula</i>	0.022	0.000
<i>Euphagus cyanocephalus</i>	0.000	0.009
<i>Molothrus ater</i>	0	0.016
<i>Icterus bullockii</i>	0	0.002
<i>Carduelis tristis</i>	0.022	0.049
Study design	Site comparison. 40	
Baseline Comparison	No information on baseline. 0	
Intra treatment variation	Replicates comparable with respect to habitat, size and location 3	
Measurement of Co-interventions	Limited information on management 0	
Replication & parameter of abundance	Replicated point counts were undertaken. 4	
Attrition bias	No losses to follow up. 2	
Sum of Data quality	49	
Notes	Information on the windfarm characteristics were not presented in the article. Information from other sources such as the NREL website was fragmentary. NREL was contacted but did not respond to our enquiries. Data was extracted from tables 1.4 and 1.5 p7-8. Information also presented on Double-crested cormorant, Great blue heron, Ring-billed gull, Mourning dove, Budgerigar, Common nighthawk, Broad-tailed hummingbird and Northern flicker.	

<b>Study</b>	Still, D., B. Little, et al. (1996). <i>The effect of wind turbines on the bird population at Blyth harbour</i> . [Harwell], ETSU.
Methods	Time series with before (Dec1991-July 1992) data and after commissioning (Jan1993-[May1995) data for abundance.
Population and co-intervention	Functional type of birds: Anseriformes, Charadriiformes Location: NE England, Coastal. Turbine type: 9 300kW wind turbines on a sea wall.

	Habitat type: maritime. Size of area: 1km <sup>2</sup> . Site management techniques: harbour, large urban population Timescale: 2 years monitoring from operation (control 1 year)		
Outcome (Abundance)	(mean monthly bird count)	Treatment (Jan93-May95)	Control (Dec91- July92)
	<i>Somateria mollissima</i>	39	98
	<i>Calidris maritima</i>	137	150
Study design	Time series:30		
Baseline Comparison	Baseline comparable:6		
Intra treatment variation	Intra-treatment variation low but some variation in functional types present: 4		
Measurement of Co-interventions	Details of site management unknown but climate changed (mild winters post windfarm operation) which could affect results (thought to be correlated with decline in Eiders): 0		
Replication & parameter of abundance	Well replicated objective abundance measure (monthly counts): 4		
Attrition bias	No losses to follow up:2		
Sum of Data quality	46		
Notes	Data on other species of bird including comorants and gulls. The monitoring was continued in a follow up study (Painter, S., Little, B. & Lawrence, S. (1999). <i>Continuation of bird studies at Blyth Harbour Wind Farm and the implications for offshore wind farms</i> . ETSU ; W/13/00495/REP. [London], DTI: 1v., various pagings.) No eider mortality was recorded from Feb1995-1999 and the authors suggest that all resident species have acclimatised to the presence of wind turbines. Replicated in Still, D., S. Painter, et al. (1997). Birds, wind farms, and Blyth Harbour. <i>Wind Energy Conversion 1996</i> : 175-183. and Still, D. (1994). <i>The birds of Blyth Harbour. Proceedings of 16th BWEA conference, Stirling, UK</i> . 16th BWEA conference, Stirling, UK, Stirling. And Still, D., Painter, S., Lawrence, E.S., Little, B. & Thomas, M.(1997). Birds, wind farms, and Blyth Harbour. <i>Wind Energy Conversion 1996</i> : 175-183. Little, B. (undated). <i>The effect of wind turbines on bird populations in Blyth Harbour</i> . Northumberland Birds?		

<b>Study</b>	Winkelman, J. E. (1992). De invloed van de Sep-windproefcentrale te Oosterbierum (Fr.) op vogels. 4. Verstoring [The impact of the Sep wind park near Oosterbierum(Fr.), the Netherlands on birds. 4. Disturbance], Netherlands. Instituut voor Bos- en Natuuronderzoek. (translated by Harma Brondijk)		
Methods	Site comparison of breeding bird numbers with baseline data before windfarm construction		
Population and co-intervention	Functional type of birds: Anseriformes, Charadriiformes, Passeriformes. Location: 3-4km inland of the Wadden sea, Holland, coastal. Windfarm design: 18 turbines, 300kW Habitat type: arable fields Size of area: 55ha, 0.55Km <sup>2</sup> . Site management techniques: farming details unknown. Timescale: monitoring from 1984-1991, windfarm operational from autumn 1990 (1 year)		
Outcome (Abundance)	Species (mean number of birds autumn 1990- spring 1991 based on 30 counts)	treatment	control
	<i>Anas platyrhynchos</i>	24.536633	346.8967
	<i>Fulica atra</i>	0.0665	254.60017
	<i>Vanellus vanellus</i>	15.392233	520.6411
	<i>Pluvialis apricaria</i>	10.533533	630.46647
	<i>Numenius arquata</i>	0.5584333	114.6749
	<i>Sturnus vulgaris</i>	84.715867	647.0508
	<i>Anas penelope</i>	0.37125	277.87875
	<i>Aythya fuligula</i>	0	8.3125
	<i>Haematopus ostralegus</i>	10.309875	180.87763

Study design	Site comparison: 40
Baseline Comparison	Abundance of species and habitat type variable, other factors comparable: 3
Intra treatment variation	No information on variation within replicates: 0
Measurement of Co-interventions	Habitat changes occurred which confound the pre farm data (increase in crops): 0
Replication & parameter of abundance	Well replicated objective parameter of abundance: 4
Attrition bias	No losses to follow up: 2
Sum of Data quality	49
Notes	Extracted data is based on appendices 10 & 11. Mean number of birds for each counting day (n=30 with each count as a replicate). The numbers in brackets are percentage in windfarm. Additional data on gulls is presented but not extracted. Also data on nest density but this is not presented in terms of a site comparison or time-series.

<b>Study</b>	Winkelman, J. E. (1989). Birds and the wind park near Urk: collision victims and disturbance of ducks, geese and swans. Arnhem, The Netherlands, Rijksinstituut voor Natuurbeheer.		
Methods	Site comparison with replicates derived from zones, plus time-series data on geese before and after farm construction.		
Population and co-intervention	Functional type of birds: Anseriformes, Charadriiformes. Location: Urk, Holland, coastal. Windfarm design: 25 300kW turbines Habitat type: arable fields Size of area: 0.5km Site management techniques: not known. Timescale: windfarm operation began 1986, data from 1988/89, 3 years		
Outcome (Abundance)	species	treatment	control
	<i>Anas platyrhynchos</i>	2.52	3.766667
	<i>Aythya ferina</i>	0.233333	0.9
	<i>Aythya fuligula</i>	0.733333	1.6
	<i>Aythya marila</i>	52.7	9.3
	<i>Bucephala clangula</i>	0.875	2.225
	<i>Fulica atra</i>	1.18	0.96
Study design	Site comparison: 40		
Baseline Comparison	No baseline reported for abundance, functional type or habitat: 2		
Intra treatment variation	Replicates comparable and balanced except with respect to distance from turbines: 3		
Measurement of Co-interventions	Unreported:0		
Replication & parameter of abundance	Well replicated objective parameter of abundance: 4		
Attrition bias	No losses to follow up: 2		
Sum of Data quality	51		
Notes	Data on gulls and Gaviformes also available. The replicates are derived from zones which have mean values. Data based on appendix 16. Table 18. shows that there are more <i>Anser fabilis</i> and <i>Anser albifrons</i> after windfarm construction than before but that <i>Branta leucopsis</i> decline. This could not be included in meta-analysis as the data is non independent of the site comparison but cannot be sensibly synthesised with it.		

Qualitative outcomes

Reference	Species	Outcome	Notes
De Lucas <i>et al.</i> (2004)	12 species of Passeriformes.	11 species are more abundant in the Wind Farm area than the control area. (abundance expressed as nests/km <sup>2</sup> ). <i>Emberiza cia</i> (Rock bunting) more abundant in control than Windfarm.	No variance is given, therefore the significance of these results is hard to assess. The data has been excluded from meta-analysis as alternative data with range is presented in the paper. Vegetation cover varies in the Wind Farm area and the control area.
Leddy <i>et al.</i> (1999)	Passeriformes	Passeriformes are more abundant in the control area than in the Wind farm area but the difference diminishes with distance from the windfarm.	This data has been excluded from meta-analysis as species data is available on the same site in another included study (Johnson, G. D., Erickson, W.P, Strickland, M.D., Shepherd, M.F. & Shepherd, D.A. (2000). <i>Avian monitoring studies at the Buffalo Ridge Wind Resource Area, Minnesota: Results of a 4-year study</i> . Technical Report prepared for Northern States Power Co., Minneapolis.).
Thomas (1999)	Charadriiformes and unspecified species	Data was collected from Ten British windfarms including data on bird abundance in windfarms and adjacent controls. There was no significant difference in species abundance and it was concluded that windfarms have a minimal impact on bird abundance.	This data has been excluded from meta-analysis as species data was lacking along with variance. The author was not contactable via the address stated in the article. The work is replicated in Thomas, R. (1999). <i>Renewable Energy and Environmental Impacts in the UK: Birds and Wind Turbines</i> . London, University College London.
Winkelman (1989)	Anseriformes	<i>Anser fabilis</i> and <i>Anser albifrons</i> are more abundant after windfarm construction than before but <i>Branta leucopsis</i> declines.	This data has been excluded from meta-analysis due to problems of independence and synthesis of spatial and temporal data within a windfarm. Additionally no variance data was presented concerning the geese spp.

**Appendix 3.** The 217 species contributing data to the abundance analysis (Latin-English, English-Latin). Species nomenclature follows Knox (1992); Taxonomy is according to the Voous classification (Campbell & Lack, 1985).

<b>Latin</b>	<b>English</b>	<b>Order</b>
<i>Accipiter cooperii</i>	Cooper's Hawk	Accipitriformes
<i>Accipiter gentilis</i>	Northern goshawk	Accipitriformes
<i>Accipiter striatus</i>	Sharp-shinned Hawk	Accipitriformes
<i>Aegithalos caudatus</i>	Long-tailed Tit	Passeriformes
<i>Agelaius phoeniceus</i>	Red-winged blackbird	Passeriformes
<i>Aix sponsa</i>	Wood duck	Anseriformes
<i>Alauda arvensis</i>	Skylark	Passeriformes
<i>Ammodramus bairdii</i>	Baird's Sparrow	Passeriformes
<i>Ammodramus savannarum</i>	Grasshopper Sparrow	Passeriformes
<i>Anas crecca</i>	Common teal	Anseriformes
<i>Anas discors</i>	Blue-winged teal	Anseriformes
<i>Anas penelope</i>	Wigeon (Eurasian)	Anseriformes
<i>Anas platyrhynchos</i>	Mallard	Anseriformes
<i>Anser albifrons</i>	White-fronted goose	Anseriformes
<i>Anser caerulescens</i>	Snow goose	Anseriformes
<i>Anthus pratensis</i>	Meadow Pipit	Passeriformes
<i>Anthus rubescens</i>	American pipit	Passeriformes
<i>Anthus trivialis</i>	Tree pipit	Passeriformes
<i>Aquila chrysaetos</i>	Golden eagle	Accipitriformes
<i>Aythya ferina</i>	Pochard (Common)	Anseriformes
<i>Aythya fuligula</i>	Tufted Duck	Anseriformes
<i>Aythya marila</i>	Greater Scaup	Anseriformes
<i>Bartramia longicauda</i>	Upland Sandpiper	Charadriiformes
<i>Bombycilla cedrorum</i>	Cedar Waxwing	Passeriformes
<i>Branta canadensis</i>	Canada goose	Anseriformes
<i>Bucephala clangula</i>	Goldeneye (Common)	Anseriformes
<i>Buteo buteo</i>	Buzzard	Accipitriformes
<i>Buteo jamaicensis</i>	Red-tailed Hawk	Accipitriformes
<i>Buteo lagopus</i>	Rough-legged Buzzard	Accipitriformes
<i>Buteo lineatus</i>	Red-shouldered hawk	Accipitriformes
<i>Buteo platypterus</i>	Broad-winged Hawk	Accipitriformes
<i>Buteo regalis</i>	Ferruginous hawk	Accipitriformes
<i>Buteo swainsoni</i>	Swainson's Hawk	Accipitriformes
<i>Calamospiza melanocorys</i>	Lark bunting	Passeriformes
<i>Calcarius lapponicus</i>	Lapland longspur	Passeriformes
<i>Calcarius mccownii</i>	McCown's Longspur	Passeriformes
<i>Calidris alpina</i>	Dunlin	Charadriiformes
<i>Calidris maritima</i>	Purple Sandpiper	Charadriiformes
<i>Calidris melanotos</i>	Pectoral Sandpiper	Charadriiformes
<i>Carduelis cannabina</i>	Linnet	Passeriformes
<i>Carduelis carduelis</i>	Goldfinch	Passeriformes
<i>Carduelis chloris</i>	Greenfinch	Passeriformes
<i>Carduelis flammea</i>	Redpoll	Passeriformes
<i>Carduelis flavirostris</i>	Twite	Passeriformes
<i>Carduelis pinus</i>	Pine siskin	Passeriformes
<i>Carduelis spinus</i>	Siskin	Passeriformes
<i>Carduelis tristis</i>	American goldfinchs	Passeriformes
<i>Carpodacus mexicanus</i>	House finch	Passeriformes
<i>Carpodacus purpureus</i>	Purple finch	Passeriformes
<i>Cathartes aura</i>	Turkey vulture	Accipitriformes
<i>Catharus guttatus</i>	Hermit thrush	Passeriformes

<i>Catharus minimus</i>	Gray cheeked Thrush	Passeriformes
<i>Catharus ustulatus</i>	Swainson's Thrush	Passeriformes
<i>Certhia americana</i>	Brown creeper	Passeriformes
<i>Certhia familiaris</i>	Treecreeper	Passeriformes
<i>Chaetura pelagica</i>	Chimney swift	Passeriformes
<i>Charadrius montanus</i>	Mountain plover	Charadriiformes
<i>Charadrius vociferus</i>	Killdeer	Charadriiformes
<i>Chondestes grammacus</i>	Lark sparrow	Passeriformes
<i>Circaetus gallicus</i>	Short-toed eagle	Accipitriformes
<i>Circus cyaneus</i>	Hen Harrier	Accipitriformes
<i>Cistothorus platensis</i>	Sedge wren	Passeriformes
<i>Clangula hyemalis</i>	Long-tailed Duck	Anseriformes
<i>Coccothraustes vespertinus</i>	Evening Grosbeak	Passeriformes
<i>Contopus cooperi</i>	Olive-sided flycatcher	Passeriformes
<i>Contopus sordidulus</i>	Western wood pewee	Passeriformes
<i>Corvus brachyrhynchos</i>	American crow	Passeriformes
<i>Corvus corax</i>	Raven	Passeriformes
<i>Corvus corone</i>	Carrion crow	Passeriformes
<i>Corvus frugilegus</i>	Rook	Passeriformes
<i>Corvus monedula</i>	Jackdaw	Passeriformes
<i>Cyanocitta cristata</i>	Blue jay	Passeriformes
<i>Cygnus olor</i>	Mute Swan	Anseriformes
<i>Dendroica caerulescens</i>	Black-throated blue warbler	Passeriformes
<i>Dendroica coronata</i>	Yellow rumped warbler	Passeriformes
<i>Dendroica fusca</i>	Blackburnian warbler	Passeriformes
<i>Dendroica magnolia</i>	Magnolia warbler	Passeriformes
<i>Dendroica palmarum</i>	Palm warbler	Passeriformes
<i>Dendroica pensylvanica</i>	Chestnut-sided warbler	Passeriformes
<i>Dendroica petechia</i>	Yellow warbler	Passeriformes
<i>Dendroica striata</i>	Blackpoll warbler	Passeriformes
<i>Dendroica virens</i>	Black throated green warbler	Passeriformes
<i>Dolichonyx oryzivorus</i>	Bobolink	Passeriformes
<i>Dryocopus pileatus</i>	Pileated woodpecker	Passeriformes
<i>Dumetella carolinensis</i>	Gray catbird	Passeriformes
<i>Emberiza citrinella</i>	Yellowhammer	Passeriformes
<i>Emberiza schoeniclus</i>	Reed Bunting	Passeriformes
<i>Empidonax minimus</i>	Least Flycatcher	Passeriformes
<i>Empidonax oberholseri</i>	Dusky flycatcher	Passeriformes
<i>Empidonax occidentalis</i>	Cordilleran flycatcher	Passeriformes
<i>Eremophila alpestris</i>	Horned lark	Passeriformes
<i>Erithacus rubecula</i>	Robin	Passeriformes
<i>Euphagus carolinus</i>	Rusty blackbird	Passeriformes
<i>Euphagus cyanocephalus</i>	Brewer's blackbird	Passeriformes
<i>Falco columbarius</i>	Merlin	Falconiformes
<i>Falco mexicanus</i>	Prairie falcon	Falconiformes
<i>Falco peregrinus</i>	Peregrine Falcon	Falconiformes
<i>Falco sparverius</i>	American Kestrel	Falconiformes
<i>Falco tinnunculus</i>	Kestrel	Falconiformes
<i>Ficedula hypoleuca</i>	Pied Flycatcher	Passeriformes
<i>Fringilla coelebs</i>	Chaffinch	Passeriformes
<i>Fulica americana</i>	American Coot	Charadriiformes
<i>Fulica atra</i>	Common Coot	Charadriiformes
<i>Gallinago gallinago</i>	Common Snipe	Charadriiformes
<i>Garrulus glandarius</i>	Jay	Passeriformes
<i>Geothlypis trichas</i>	Common yellowthroat	Passeriformes
<i>Guiraca caerulea</i>	Blue grosbeak	Passeriformes
<i>Gyps fulvus</i>	Griffon Vulture	Accipitriformes
<i>Haematopus ostralegus</i>	Oystercatcher	Charadriiformes

<i>Haliaeetus leucocephalus</i>	Bald Eagle	Accipitriformes
<i>Hirundo rustica</i>	Swallow	Passeriformes
<i>Icterus bullockii</i>	Bullock's oriole	Passeriformes
<i>Icterus galbula</i>	Baltimore oriole	Passeriformes
<i>Icterus spurius</i>	Orchard oriole	Passeriformes
<i>Junco hyemalis</i>	Dark-eyed Junco	Passeriformes
<i>Lanius excubitor</i>	Northern shrike	Passeriformes
<i>Limosa limosa</i>	Black-tailed Godwit	Charadriiformes
<i>Melanitta nigra</i>	Common scoter	Anseriformes
<i>Melospiza georgiana</i>	Swamp sparrow	Passeriformes
<i>Melospiza lincolnii</i>	Lincoln's sparrow	Passeriformes
<i>Melospiza melodia</i>	Song sparrow	Passeriformes
<i>Mergus merganser</i>	Common Merganser (Goosander)	Anseriformes
<i>Mergus serrator</i>	Red-breasted Merganser	Anseriformes
<i>Milvus migrans</i>	Black kite	Accipitriformes
<i>Mniotilta varia</i>	Black and white warbler	Passeriformes
<i>Molothrus ater</i>	Brown-headed cowbird	Passeriformes
<i>Motacilla alba</i>	Pied (White) Wagtail	Passeriformes
<i>Motacilla cinerea</i>	Grey Wagtail	Passeriformes
<i>Muscicapa striata</i>	Spotted Flycatcher	Passeriformes
<i>Numenius americanus</i>	Long billed curlew	Charadriiformes
<i>Numenius arquata</i>	Curlew (Eurasian)	Charadriiformes
<i>Oenanthe oenanthe</i>	Wheatear (Northern)	Passeriformes
<i>Oporornis agilis</i>	Connecticut warbler	Passeriformes
<i>Oporornis tolmiei</i>	Macgillivray's Warbler	Passeriformes
<i>Oreoscoptes montanus</i>	Sage thrasher	Passeriformes
<i>Pandion haliaetus</i>	Osprey	Accipitriformes
<i>Parus ater</i>	Coal Tit	Passeriformes
<i>Parus caeruleus</i>	Blue Tit	Passeriformes
<i>Parus major</i>	Great Tit	Passeriformes
<i>Parus montanus</i>	Willow Tit	Passeriformes
<i>Parus palustris</i>	Marsh Tit	Passeriformes
<i>Passer domesticus</i>	House Sparrow	Passeriformes
<i>Passerculus sandwichensis</i>	Savannah Sparrow	Passeriformes
<i>Petrochelidon pyrrhonota</i>	Cliff swallow	Passeriformes
<i>Phalaropus tricolor</i>	Wilson's phalarope	Charadriiformes
<i>Pheucticus ludovicianus</i>	Rose-breasted Grosbeak	Passeriformes
<i>Phoenicurus phoenicurus</i>	Redstart (Common)	Passeriformes
<i>Phylloscopus sibilatrix</i>	Wood Warbler	Passeriformes
<i>Phylloscopus trochilus</i>	Willow Warbler	Passeriformes
<i>Pica hudsonia</i>	Black billed magpie	Passeriformes
<i>Pica pica</i>	Magpie	Passeriformes
<i>Picoides pubescens</i>	Downy woodpecker	Passeriformes
<i>Picoides villosus</i>	Hairy woodpecker	Passeriformes
<i>Pipilo chlorurus</i>	Green tailed Towhee	Passeriformes
<i>Pipilo maculatus</i>	Spotted Towhee	Passeriformes
<i>Piranga olivacea</i>	Scarlet tanager	Passeriformes
<i>Pluvialis apricaria</i>	Golden plover	charadriiformes
<i>Pluvialis dominica</i>	American Golden-plover	charadriiformes
<i>Poecile atricapilla</i>	Black capped chickadee	Passeriformes
<i>Pooecetes gramineus</i>	Vesper sparrow	Passeriformes
<i>Prunella modularis</i>	Dunnock (Hedge Accentor)	Passeriformes
<i>Pyrrhula pyrrhula</i>	Bullfinch	Passeriformes
<i>Quiscalus quiscula</i>	Common grackle	Passeriformes
<i>Regulus calendula</i>	Ruby-crowned Kinglet	Passeriformes
<i>Regulus regulus</i>	Goldcrest	Passeriformes
<i>Regulus satrapa</i>	Golden crowned kinglet	Passeriformes
<i>Riparia riparia</i>	Bank swallow	Passeriformes

<i>Salpinctes obsoletus</i>	Rock wren	Passeriformes
<i>Saxicola rubetra</i>	Whinchat	Passeriformes
<i>Saxicola torquata</i>	Stonechat	Passeriformes
<i>Sayornis phoebe</i>	Eastern Phoebe	Passeriformes
<i>Sayornis saya</i>	Say's Phoebe	Passeriformes
<i>Seiurus aurocapillus</i>	Ovenbird	Passeriformes
<i>Setophaga ruticilla</i>	American redstart	Passeriformes
<i>Sialia currucoides</i>	Mountain Bluebird	Passeriformes
<i>Sialia sialis</i>	Eastern bluebird	Passeriformes
<i>Sitta canadensis</i>	Red-breasted nuthatch	Passeriformes
<i>Sitta carolinensis</i>	White-breasted nuthatch	Passeriformes
<i>Sitta europaea</i>	Nuthatch	Passeriformes
<i>Somateria mollissima</i>	Eider	Anseriformes
<i>Sphyrapicus varius</i>	Yellow-bellied sapsucker	Passeriformes
<i>Spiza americana</i>	Dickcissel	Passeriformes
<i>Spizella arborea</i>	American tree sparrow	Passeriformes
<i>Spizella breweri</i>	Brewers sparrow	Passeriformes
<i>Spizella pallida</i>	Clay colored Sparrow	Passeriformes
<i>Spizella passerina</i>	Chipping sparrow	Passeriformes
<i>Stelgidopteryx serripennis</i>	Northern rough-winged Swallow	Passeriformes
<i>Sturnella neglecta</i>	Western meadowlark	Passeriformes
<i>Sturnus vulgaris</i>	Starling	Passeriformes
<i>Sylvia atricapilla</i>	Blackcap	Passeriformes
<i>Sylvia borin</i>	Garden Warbler	Passeriformes
<i>Sylvia communis</i>	Whitethroat	Passeriformes
<i>Tachycineta bicolor</i>	Tree Swallow	Passeriformes
<i>Tachycineta thalassina</i>	Violet green Swallow	Passeriformes
<i>Tadorna tadorna</i>	Shelduck	Anseriformes
<i>Toxostoma rufum</i>	Brown thrasher	Passeriformes
<i>Tringa melanoleuca</i>	Greater Yellowlegs	Charadriiformes
<i>Tringa totanus</i>	Common Redshank	Charadriiformes
<i>Troglodytes aedon</i>	House wren	Passeriformes
<i>Troglodytes troglodytes</i>	Wren (Winter)	Passeriformes
<i>Turdus merula</i>	Blackbird	Passeriformes
<i>Turdus migratorius</i>	American robin	Passeriformes
<i>Turdus philomelos</i>	Song Thrush	Passeriformes
<i>Turdus viscivorus</i>	Mistle Thrush	Passeriformes
<i>Tyrannus tyrannus</i>	Eastern Kingbird	Passeriformes
<i>Tyrannus verticalis</i>	Western kingbird	Passeriformes
<i>Vanellus vanellus</i>	Lapwing	Charadriiformes
<i>Vermivora celata</i>	Orange crowned Warbler	Passeriformes
<i>Vermivora peregrina</i>	Tennessee warbler	Passeriformes
<i>Vireo gilvus</i>	Warbling vireo	Passeriformes
<i>Vireo olivaceus</i>	Red-eyed vireo	Passeriformes
<i>Vireo solitarius</i>	Solitary Vireo	Passeriformes
<i>Wilsonia canadensis</i>	Canada warbler	Passeriformes
<i>Xanthocephalus xanthocephalus</i>	Yellow-headed Blackbird	Passeriformes
<i>Zonotrichia albicollis</i>	White-throated Sparrow	Passeriformes
<i>Zonotrichia leucophrys</i>	White-crowned Sparrow	Passeriformes
<i>Zonotrichia querula</i>	Harris's sparrow	Passeriformes

<b>English</b>	<b>Latin</b>	<b>Order</b>
American Coot	<i>Fulica americana</i>	Charadriiformes
American crow	<i>Corvus brachyrhynchos</i>	Passeriformes
American Golden-plover	<i>Pluvialis dominica</i>	charadriiformes
American goldfinchs	<i>Carduelis tristis</i>	Passeriformes
American Kestrel	<i>Falco sparverius</i>	Falconiformes
American pipit	<i>Anthus rubescens</i>	Passeriformes

American redstart	<i>Setophaga ruticilla</i>	Passeriformes
American robin	<i>Turdus migratorius</i>	Passeriformes
American tree sparrow	<i>Spizella arborea</i>	Passeriformes
Baird's Sparrow	<i>Ammodramus bairdii</i>	Passeriformes
Bald Eagle	<i>Haliaeetus leucocephalus</i>	Accipitriformes
Baltimore oriole	<i>Icterus galbula</i>	Passeriformes
Bank swallow	<i>Riparia riparia</i>	Passeriformes
Black and white warbler	<i>Mniotilta varia</i>	Passeriformes
Black billed magpie	<i>Pica hudsonia</i>	Passeriformes
Black capped chickadee	<i>Poecile atricapilla</i>	Passeriformes
Black kite	<i>Milvus migrans</i>	Accipitriformes
Black throated green warbler	<i>Dendroica virens</i>	Passeriformes
Blackbird	<i>Turdus merula</i>	Passeriformes
Blackburnian warbler	<i>Dendroica fusca</i>	Passeriformes
Blackcap	<i>Sylvia atricapilla</i>	Passeriformes
Blackpoll warbler	<i>Dendroica striata</i>	Passeriformes
Black-tailed Godwit	<i>Limosa limosa</i>	Charadriiformes
Black-throated blue warbler	<i>Dendroica caerulescens</i>	Passeriformes
Blue grosbeak	<i>Guiraca caerulea</i>	Passeriformes
Blue jay	<i>Cyanocitta cristata</i>	Passeriformes
Blue Tit	<i>Parus caeruleus</i>	Passeriformes
Blue-winged teal	<i>Anas discors</i>	Anseriformes
Bobolink	<i>Dolichonyx oryzivorus</i>	Passeriformes
Brewer's blackbird	<i>Euphagus cyanocephalus</i>	Passeriformes
Brewers sparrow	<i>Spizella breweri</i>	Passeriformes
Broad-winged Hawk	<i>Buteo platypterus</i>	Accipitriformes
Brown creeper	<i>Certhia americana</i>	Passeriformes
Brown thrasher	<i>Toxostoma rufum</i>	Passeriformes
Brown-headed cowbird	<i>Molothrus ater</i>	Passeriformes
Bullfinch	<i>Pyrrhula pyrrhula</i>	Passeriformes
Bullock's oriole	<i>Icterus bullockii</i>	Passeriformes
Buzzard	<i>Buteo buteo</i>	Accipitriformes
Canada goose	<i>Branta canadensis</i>	Anseriformes
Canada warbler	<i>Wilsonia canadensis</i>	Passeriformes
Carrion crow	<i>Corvus corone</i>	Passeriformes
Cedar Waxwing	<i>Bombycilla cedrorum</i>	Passeriformes
Chaffinch	<i>Fringilla coelebs</i>	Passeriformes
Chestnut-sided warbler	<i>Dendroica pensylvanica</i>	Passeriformes
Chimney swift	<i>Chaetura pelagica</i>	Passeriformes
Chipping sparrow	<i>Spizella passerina</i>	Passeriformes
Clay colored Sparrow	<i>Spizella pallida</i>	Passeriformes
Cliff swallow	<i>Petrochelidon pyrrhonota</i>	Passeriformes
Coal Tit	<i>Parus ater</i>	Passeriformes
Common Coot	<i>Fulica atra</i>	Charadriiformes
Common grackle	<i>Quiscalus quiscula</i>	Passeriformes
Common Merganser (Goosander)	<i>Mergus merganser</i>	Anseriformes
Common Redshank	<i>Tringa totanus</i>	Charadriiformes
Common scoter	<i>Melanitta nigra</i>	Anseriformes
Common Snipe	<i>Gallinago gallinago</i>	Charadriiformes
Common teal	<i>Anas crecca</i>	Anseriformes
Common yellowthroat	<i>Geothlypis trichas</i>	Passeriformes
Connecticut warbler	<i>Oporornis agilis</i>	Passeriformes
Cooper's Hawk	<i>Accipiter cooperii</i>	Accipitriformes
Cordilleran flycatcher	<i>Empidonax occidentalis</i>	Passeriformes
Curlew (Eurasian)	<i>Numenius arquata</i>	Charadriiformes
Dark-eyed Junco	<i>Junco hyemalis</i>	Passeriformes
Dickcissel	<i>Spiza americana</i>	Passeriformes
Downy woodpecker	<i>Picoides pubescens</i>	Passeriformes

Dunlin	<i>Calidris alpina</i>	Charadriiformes
Dunnock (Hedge Accentor)	<i>Prunella modularis</i>	Passeriformes
Dusky flycatcher	<i>Empidonax oberholseri</i>	Passeriformes
Eastern bluebird	<i>Sialia sialis</i>	Passeriformes
Eastern Kingbird	<i>Tyrannus tyrannus</i>	Passeriformes
Eastern Phoebe	<i>Sayornis phoebe</i>	Passeriformes
Eider	<i>Somateria mollissima</i>	Anseriformes
Evening Grosbeak	<i>Coccothraustes vespertinus</i>	Passeriformes
Ferruginous hawk	<i>Buteo regalis</i>	Accipitriformes
Garden Warbler	<i>Sylvia borin</i>	Passeriformes
Goldcrest	<i>Regulus regulus</i>	Passeriformes
Golden crowned kinglet	<i>Regulus satrapa</i>	Passeriformes
Golden eagle	<i>Aquila chrysaetos</i>	Accipitriformes
Golden plover	<i>Pluvialis apricaria</i>	charadriiformes
Goldeneye (Common)	<i>Bucephala clangula</i>	Anseriformes
Goldfinch	<i>Carduelis carduelis</i>	Passeriformes
Grasshopper Sparrow	<i>Ammodramus savannarum</i>	Passeriformes
Gray catbird	<i>Dumetella carolinensis</i>	Passeriformes
Gray cheeked Thrush	<i>Catharus minimus</i>	Passeriformes
Great Tit	<i>Parus major</i>	Passeriformes
Greater Scaup	<i>Aythya marila</i>	Anseriformes
Greater Yellowlegs	<i>Tringa melanoleuca</i>	Charadriiformes
Green tailed Towhee	<i>Pipilo chlorurus</i>	Passeriformes
Greenfinch	<i>Carduelis chloris</i>	Passeriformes
Grey Wagtail	<i>Motacilla cinerea</i>	Passeriformes
Griffon Vulture	<i>Gyps fulvus</i>	Accipitriformes
Hairy woodpecker	<i>Picoides villosus</i>	Passeriformes
Harris's sparrow	<i>Zonotrichia querula</i>	Passeriformes
Hen Harrier	<i>Circus cyaneus</i>	Accipitriformes
Hermit thrush	<i>Catharus guttatus</i>	Passeriformes
Horned lark	<i>Eremophila alpestris</i>	Passeriformes
House finch	<i>Carpodacus mexicanus</i>	Passeriformes
House Sparrow	<i>Passer domesticus</i>	Passeriformes
House wren	<i>Troglodytes aedon</i>	Passeriformes
Jackdaw	<i>Corvus monedula</i>	Passeriformes
Jay	<i>Garrulus glandarius</i>	Passeriformes
Kestrel	<i>Falco tinnunculus</i>	Falconiformes
Killdeer	<i>Charadrius vociferus</i>	Charadriiformes
Lapland longspur	<i>Calcarius lapponicus</i>	Passeriformes
Lapwing	<i>Vanellus vanellus</i>	Charadriiformes
Lark bunting	<i>Calamospiza melanocorys</i>	Passeriformes
Lark sparrow	<i>Chondestes grammacus</i>	Passeriformes
Least Flycatcher	<i>Empidonax minimus</i>	Passeriformes
Lincoln's sparrow	<i>Melospiza lincolnii</i>	Passeriformes
Linnet	<i>Carduelis cannabina</i>	Passeriformes
Long billed curlew	<i>Numenius americanus</i>	Charadriiformes
Long-tailed Duck	<i>Clangula hyemalis</i>	Anseriformes
Long-tailed Tit	<i>Aegithalos caudatus</i>	Passeriformes
Macgillivray's Warbler	<i>Oporornis tolmiei</i>	Passeriformes
Magnolia warbler	<i>Dendroica magnolia</i>	Passeriformes
Magpie	<i>Pica pica</i>	Passeriformes
Mallard	<i>Anas platyrhynchos</i>	Anseriformes
Marsh Tit	<i>Parus palustris</i>	Passeriformes
McCown's Longspur	<i>Calcarius mccownii</i>	Passeriformes
Meadow Pipit	<i>Anthus pratensis</i>	Passeriformes
Merlin	<i>Falco columbarius</i>	Falconiformes
Mistle Thrush	<i>Turdus viscivorus</i>	Passeriformes
Mountain Bluebird	<i>Sialia currucoides</i>	Passeriformes

Mountain plover	<i>Charadrius montanus</i>	Charadriiformes
Mute Swan	<i>Cygnus olor</i>	Anseriformes
Northern goshawk	<i>Accipiter gentilis</i>	Accipitriformes
Northern rough-winged Swallow	<i>Stelgidopteryx serripennis</i>	Passeriformes
Northern shrike	<i>Lanius excubitor</i>	Passeriformes
Nuthatch	<i>Sitta europaea</i>	Passeriformes
Olive-sided flycatcher	<i>Contopus cooperi</i>	Passeriformes
Orange crowned Warbler	<i>Vermivora celata</i>	Passeriformes
Orchard oriole	<i>Icterus spurius</i>	Passeriformes
Osprey	<i>Pandion haliaetus</i>	Accipitriformes
Ovenbird	<i>Seiurus aurocapillus</i>	Passeriformes
Oystercatcher	<i>Haematopus ostralegus</i>	Charadriiformes
Palm warbler	<i>Dendroica palmarum</i>	Passeriformes
Pectoral Sandpiper	<i>Calidris melanotos</i>	Charadriiformes
Peregrine Falcon	<i>Falco peregrinus</i>	Falconiformes
Pied (White) Wagtail	<i>Motacilla alba</i>	Passeriformes
Pied Flycatcher	<i>Ficedula hypoleuca</i>	Passeriformes
Pileated woodpecker	<i>Dryocopus pileatus</i>	Passeriformes
Pine siskin	<i>Carduelis pinus</i>	Passeriformes
Pochard (Common)	<i>Aythya ferina</i>	Anseriformes
Prairie falcon	<i>Falco mexicanus</i>	Falconiformes
Purple finch	<i>Carpodacus purpureus</i>	Passeriformes
Purple Sandpiper	<i>Calidris maritima</i>	Charadriiformes
Raven	<i>Corvus corax</i>	Passeriformes
Red-breasted nuthatch	<i>Sitta canadensis</i>	Passeriformes
Red-breasted Merganser	<i>Mergus serrator</i>	Anseriformes
Red-eyed vireo	<i>Vireo olivaceus</i>	Passeriformes
Redpoll	<i>Carduelis flammea</i>	Passeriformes
Red-shouldered hawk	<i>Buteo lineatus</i>	Accipitriformes
Redstart (Common)	<i>Phoenicurus phoenicurus</i>	Passeriformes
Red-tailed Hawk	<i>Buteo jamaicensis</i>	Accipitriformes
Red-winged blackbird	<i>Agelaius phoeniceus</i>	Passeriformes
Reed Bunting	<i>Emberiza schoeniclus</i>	Passeriformes
Robin	<i>Erithacus rubecula</i>	Passeriformes
Rock wren	<i>Salpinctes obsoletus</i>	Passeriformes
Rook	<i>Corvus frugilegus</i>	Passeriformes
Rose-breasted Grosbeak	<i>Pheucticus ludovicianus</i>	Passeriformes
Rough-legged Buzzard	<i>Buteo lagopus</i>	Accipitriformes
Ruby-crowned Kinglet	<i>Regulus calendula</i>	Passeriformes
Rusty blackbird	<i>Euphagus carolinus</i>	Passeriformes
Sage thrasher	<i>Oreoscoptes montanus</i>	Passeriformes
Savannah Sparrow	<i>Passerculus sandwichensis</i>	Passeriformes
Say's Phoebe	<i>Sayornis saya</i>	Passeriformes
Scarlet tanager	<i>Piranga olivacea</i>	Passeriformes
Sedge wren	<i>Cistothorus platensis</i>	Passeriformes
Sharp-shinned Hawk	<i>Accipiter striatus</i>	Accipitriformes
Shelduck	<i>Tadorna tadorna</i>	Anseriformes
Short-toed eagle	<i>Circaetus gallicus</i>	Accipitriformes
Siskin	<i>Carduelis spinus</i>	Passeriformes
Skylark	<i>Alauda arvensis</i>	Passeriformes
Snow goose	<i>Anser caerulescens</i>	Anseriformes
Solitary Vireo	<i>Vireo solitarius</i>	Passeriformes
Song sparrow	<i>Melospiza melodia</i>	Passeriformes
Song Thrush	<i>Turdus philomelos</i>	Passeriformes
Spotted Flycatcher	<i>Muscicapa striata</i>	Passeriformes
Spotted Towhee	<i>Pipilo maculatus</i>	Passeriformes
Starling	<i>Sturnus vulgaris</i>	Passeriformes
Stonechat	<i>Saxicola torquata</i>	Passeriformes

Swainson's Hawk	<i>Buteo swainsoni</i>	Accipitriformes
Swainson's Thrush	<i>Catharus ustulatus</i>	Passeriformes
Swallow	<i>Hirundo rustica</i>	Passeriformes
Swamp sparrow	<i>Melospiza georgiana</i>	Passeriformes
Tennessee warbler	<i>Vermivora peregrina</i>	Passeriformes
Tree pipit	<i>Anthus trivialis</i>	Passeriformes
Tree Swallow	<i>Tachycineta bicolor</i>	Passeriformes
Treecreeper	<i>Certhia familiaris</i>	Passeriformes
Tufted Duck	<i>Aythya fuligula</i>	Anseriformes
Turkey vulture	<i>Cathartes aura</i>	Accipitriformes
Twite	<i>Carduelis flavirostris</i>	Passeriformes
Upland Sandpiper	<i>Bartramia longicauda</i>	Charadriiformes
Vesper sparrow	<i>Poocetes gramineus</i>	Passeriformes
Violet green Swallow	<i>Tachycineta thalassina</i>	Passeriformes
Warbling vireo	<i>Vireo gilvus</i>	Passeriformes
Western kingbird	<i>Tyrannus verticalis</i>	Passeriformes
Western meadowlark	<i>Sturnella neglecta</i>	Passeriformes
Western wood pewee	<i>Contopus sordidulus</i>	Passeriformes
Wheatear (Northern)	<i>Oenanthe oenanthe</i>	Passeriformes
Whinchat	<i>Saxicola rubetra</i>	Passeriformes
White-breasted nuthatch	<i>Sitta carolinensis</i>	Passeriformes
White-crowned Sparrow	<i>Zonotrichia leucophrys</i>	Passeriformes
White-fronted goose	<i>Anser albifrons</i>	Anseriformes
Whitethroat	<i>Sylvia communis</i>	Passeriformes
White-throated Sparrow	<i>Zonotrichia albicollis</i>	Passeriformes
Wigeon (Eurasian)	<i>Anas penelope</i>	Anseriformes
Willow Tit	<i>Parus montanus</i>	Passeriformes
Willow Warbler	<i>Phylloscopus trochilus</i>	Passeriformes
Wilson's phalarope	<i>Phalaropus tricolor</i>	Charadriiformes
Wood duck	<i>Aix sponsa</i>	Anseriformes
Wood Warbler	<i>Phylloscopus sibilatrix</i>	Passeriformes
Wren (Winter)	<i>Troglodytes troglodytes</i>	Passeriformes
Yellow rumped warbler	<i>Dendroica coronata</i>	Passeriformes
Yellow warbler	<i>Dendroica petechia</i>	Passeriformes
Yellow-bellied sapsucker	<i>Sphyrapicus varius</i>	Passeriformes
Yellowhammer	<i>Emberiza citrinella</i>	Passeriformes
Yellow-headed Blackbird	<i>Xanthocephalus xanthocephalus</i>	Passeriformes