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EFFECTS OF WIND TURBINES ON BIRD ABUNDANCE

Systematic Review

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CENTRE FOR EVIDENCE-BASED CONSERVATION

SYSTEMATIC REVIEW NO. 4

Effects of wind turbines on bird abundance
Review Report

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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 Charadriformes (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 Charadriformes 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^2. 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^2), 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 windturbines", 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.

Sample size	Conversion Factor
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, *et al.* (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 *et al.* (1998)	Denmark, offshore	Anseriformes	2	Marine	500	10			Mussel availability is correlated with sea duck decline	Temporal replication of observations in treatment and control	Excluded from WMD meta-analysis as there are <3 species. Included in all SMD analyses
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 *et al.* (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 *et al.* (2000) 2.					750	143	2				
Johnson, Erickson *et al.* (2000) 3.						138	1				
Johnson, Young *et al.* (2000)	Wyoming, inland		71	Scrub / brushwood	647	105					Included only in SMD sensitivity analysis as there is no variance data with which to weight the study at the individual species level.
Kerlinger (2002)	Vermont, inland	Accipitriformes, Falconiformes & Passeriformes	54	Forest	550	11		Time series		Spatial replication of observations before and after windfarm construction	

Ketzenberg *et al.* (2002) 1.	Saxony, coastal	Charadriformes	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 *et al.* (2002) 2.						34					
Ketzenberg *et al.* (2002) 3.			3			17					
Ketzenberg *et al.* (2002) 4.			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 *et al.*(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			Spatial replication of observations in treatment and control	Included in all analyses
Schmidt *et al.* (2003)	Colorado, inland		38	Grassland	Unknown				None known		Included only in SMD Sensitivity analysis as there is no windfarm characteristics data
Still *et al.* (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, Charadriformes, Passeriformes	9	Arable		18	1		Habitat changes occurred (increase in crops) which confound the baseline but are equal in treatment and control	Spatial replication of observations in treatment and control after windfarm construction	

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.

	Main Pooled Effect				**Individual** taxon **effects**	
study	**Pooled Effect size**	**P**	**Q**	**bias**	**Significant positive effect size**	**Significant negative effect size**
De Lucas et al. (2004)	-0.699	0.383	**111.269**	-2.316	-	*Passeriformes, Milvus migrans*
Larsson (1994)	**-2.673**	**0.001**	8.109	1.492	-	*Clangula hyemalis, Mergus serrator*
Meek et al.(1993)	-3.762	0.762	**70.245**	insufficient strata	Charadriformes	Passeriformes
Phillips (1994)	-5.6×10^{12}	0.999	50.918	0.046	-	-
Winkelman (1992)	**-275.771**	**< 0.0001**	**263.339**	**-5.212**	-	*Anas platyrhynchos, Anas penelope, Fulica atra, Vanellus vanellus, Pluvialis apricaria, Numenius arquata, Haematopus ostralegus, Sturnus vulgaris*
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 Charadriformes, 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	**0.0001**	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	**0.004**	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	**0.002**	-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	**0.001**	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	Location	Latitude	Turbine number	Turbine power	Habitat type	Size of area	Time since operation	Migrant	Data quality	Effect size
Taxon	1										
Location	**0.777**	1									
	0.00001										
Latitude	-0.152	**-0.397**	1								
	0.159	***0.0001***									
Turbine number	0.002	0.066	-0.177	1							
	0.981	*0.542*	*0.099*								
Turbine power	**0.295**	0.023	**0.809**	-0.179	1						
	0.005	*0.832*	***0.00001***	*0.096*							
Habitat type	-0.248	0.027	**-0.726**	0.034	**-0.842**	1					
	0.02	*0.799*	***0.00001***	*0.748*	***0.00001***						
Size of area	0.119	0.15	-0.097	**0.984**	-0.034	-0.099	1				
	0.271	*0.163*	*0.367*	***0.00001***	*0.754*	*0.361*					
Time since operation	-0.255	0.034	-0.221	**0.68**	**-0.421**	0.223	**0.606**	1			
	0.016	*0.752*	*0.0391*	***0.00001***	***0.00001***	*0.037*	***0.00001***				
Migrant	0.171	0.164	**-0.294**	0.091	-0.16	0.139	0.087	-0.002	1		
	0.113	*0.128*	***0.005***	*0.4*	*0.138*	*0.198*	*0.421*	*0.982*			
Data quality	**0.308**	0.009	**0.721**	-0.104	**0.854**	**-0.913**	0.043	**-0.424**	-0.1	1	
	0.003	*0.931*	***0.00001***	*0.338*	***0.00001***	***0.00001***	*0.692*	***0.00001***	*0.353*		
Effect size	**0.371**	**0.465**	-0.138	-0.082	0.156	-0.1371	-0.02	-0.021	-0.0004	0.122	1
	0.0004	***0.00001***	*0.199*	*0.449*	*0.1475*	*0.2055*	*0.853*	*0.843*	*0.996*	*0.256*	

Discussion

Our analyses suggest that windfarms can have a negative impact on bird abundance especially amongst Anseriformes and Charadriformes. However, there is statistically significant heterogeneity in results, and on occasion windfarms do not have a negative impact for individual taxon. For example, Charadriformes (*Calidris alpine* 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 concensus 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 Charadriformes, 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. Charadriformes were considered vulnerable to disturbance displacement and barrier to movement, Accipitiformes to disturbance displacement and collision, Passeriformes (especially noctural 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 Charadriformes 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 Charadriformes 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.

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

Appendix Two: *Table of included studies.*

<table>
<tr><td>Study</td><td colspan="3">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. Biodiversity and Conservation 13(2): 395-407.</td></tr>
<tr><td>Methods</td><td colspan="3">Bird counts along one transect repeated in time in treatment and control site.</td></tr>
<tr><td>Population and co-intervention</td><td colspan="3">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 Quercus spp.
Size of area: Wind farm study area transect is 2780m long. Area is defined as 2.7Km^2.
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.</td></tr>
<tr><td rowspan="7">Outcome (Abundance)</td><td colspan="3">Mean number birds/km along one transect replicated through time . n=228, sd derived from range.</td></tr>
<tr><td>Species</td><td>Treatment (windfarm)</td><td>Control</td></tr>
<tr><td>Passeriformes</td><td>8.5</td><td>69</td></tr>
<tr><td>Gyps fulvus</td><td>8.88</td><td>5.23</td></tr>
<tr><td>Circaetus gallicus</td><td>0.92</td><td>0.72</td></tr>
<tr><td>Falco tinnunculus</td><td>0.6</td><td>0.62</td></tr>
<tr><td>Milvus migrans</td><td>25.94</td><td>34.43</td></tr>
<tr><td>Study design</td><td colspan="3">Site comparison. 40</td></tr>
<tr><td>Baseline Comparison</td><td colspan="3">No information on baseline. 0</td></tr>
<tr><td>Intra treatment variation</td><td colspan="3">No spatial replicates. No information on temporal variation. 0</td></tr>
<tr><td>Measurement of Co-interventions</td><td colspan="3">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</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="3">Linear transects were walked with temporal replication. Bird species and number were recorded along with other unreported variables. 4</td></tr>
<tr><td>Attrition bias</td><td colspan="3">No losses to follow up. 2</td></tr>
<tr><td>Sum of Data quality</td><td colspan="3">46</td></tr>
<tr><td>Notes</td><td colspan="3">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).</td></tr>
</table>

<table>
<tr><td>Study</td><td>Guillemette, M., Larsen, J.K. & Clausager, I. (1998) Impact assessment of an off-shore wind park on sea ducks. Neri Technical report no 227.</td></tr>
<tr><td>Methods</td><td>Before and after site comparison based on bird counts.</td></tr>
<tr><td>Population and co-intervention</td><td>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^2.
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).</td></tr>
<tr><td>Outcome (Abundance)</td><td>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).</td></tr>
</table>

	Species	Treatment (windfarm)	Control
	Somateria mollissima	458	1958
	Melanitta nigra	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.		

Study	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^2. 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^2 per road survey. (n=16 treatment, n=2 control)		
	Species	Treatment (windfarm)	Control
	Aquila chrysaetos	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^2 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.

Study	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.
Methods	BACI design monitoring of bird abundance (3 sites and one non independent control).
Population and co-intervention	Functional type of birds: Accipitriformes, Anseriformes, Charadriiformes, Falconiformes and Passeriformes. Location: Buffalo ridge, Minnesota, inland. Windfarm design: P1 73 turbines 342kW (25MW plant), P2 143 turbines 750kW (107.25MW plant), P3 138 turbines 750kW (103.5MW plant). Habitat type: arable. Size of area: P1 12.75Km^2, P2 47Km^2, P3 47Km^2 (P1, 8.5miles, P2/P3 25-38miles). Site management techniques: unknown. Timescale: monitoring from 1996 to 1999. operation began in 1994 P1, 1998 P2, 1999 P3. Timescale = 3yrs P1, 2yrs P2, 1yr P1.
Outcome (Abundance)	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).

Species		Treatment (windfarm)			Control
		P1	P2	P3	
Mergus merganser	sp	0	0.01	0	0.01
Anas platyrhynchos	sp	0.1	0.28	0.19	0.13
Anas discors	sp	0.01	0.01	0.03	0.01
Anas crecca	sp	0	0.01	0	0.01
Aix sponsa	sp	0.01	0.02	0.01	0.01
Branta canadensis	sp	0.11	0.06	0.18	0.25
Anser caerulescens	sp	0	0.09	0	0.16
Anser albifrons	sp	0	0	0	0.16
Fulica americana	a	0	0	0	0.01
Bartramia longicauda	s	0.01	0.02	0.05	0.06
Pluvialis dominica	sp	0.02	0.03	0.14	0.15
Charadrius vociferus	s	0.09	0.23	0.12	0.25
Calidris melanotos	s	0	0	0.1	0.02
Tringa melanoleuca	sp	0	0.02	0.01	0.01
Gallinago gallinago	sp	0.01	0.01	0.03	0.03
Circus cyaneus	sp	0.01	0.03	0.02	0.02
Accipiter striatus	a	0	0.01	0.01	0.01
Accipiter cooperii	s	0	0	0	0.01
Buteo platypterus	sp	0.01	0.01	0	0.01
Buteo jamaicensis	a	0.02	0.04	0.04	0.05
Buteo swainsoni	a	0.01	0.01	0.01	0.01
Buteo lagopus	a	0	0.01	0	0.01
Haliaeetus leucocephalus	a	0	0	0	0.01
Falco columbarius	sp	0	0	0	0.01
Falco sparverius	s	0.01	0.01	0.02	0.03
Tyrannus tyrannus	s	0.01	0.06	0.07	0.16
Tyrannus verticalis	s	0.01	0.02	0	0.02
Sayornis phoebe	a	0	0	0	0.01
Empidonax minimus	sp	0.01	0.01	0	0.01
Eremophila alpestris	a	0.19	1.34	0.46	0.82

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

	Dendroica palmarum	sp	0	0	0.01	0.01
	Dendroica petechia	sp	0.01	0.01	0	0.02
	Dendroica coronata	sp	0	0.01	0.01	0.02
	Passer domesticus	a	0.04	0.1	0.11	0.12
	Dumetella carolinensis	s	0.01	0.01	0.01	0.01
	Toxostoma rufum	s	0.01	0.01	0.02	0.02
	Troglodytes aedon	s	0.01	0.03	0.06	0.08
	Cistothorus platensis	s	0.17	0.12	0.1	0.03
	Regulus calendula	sp	0	0.01	0.01	0.01
	Poecile atricapilla	a	0.01	0.01	0.01	0.03
	Catharus guttatus	sp	0.01	0	0	0.01
	Catharus minimus	sp	0	0	0	0.01
	Turdus migratorius	a	0.15	0.18	0.15	0.24
	Sialia sialis	a	0.01	0.02	0	0.06
	Lanius excubitor	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	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. & Naugle, D. E. (1999) Effects of wind turbines on upland nesting birds in Conservation Reserve Program grasslands. Wilson Bulletin **111**(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.					

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

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

	Pipilo chlorurus	0.248	0.027
	Calcarius mccownii	0	0.271
	Passerculus sandwichensis	0.013	0.015
	Melospiza melodia	0.015	0.005
	Melospiza lincolnii	0.005	0
	Zonotrichia leucophrys	0.017	0
	Chondestes grammacus	0	0.005
	Ammodramus bairdii	0.005	0
	Pooecetes gramineus	0.927	1.271
	***S**pizella breweri*	0.448	0.771
	Spizella passerina	0.106	0
	Junco hyemalis	0.005	0
	Calamospiza melanocorys	0.01	0.019
	Bombycilla cedrorum	0.008	0
	Poecile atricapilla	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.		

Study	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 $0.05Km^2$. 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)
	Corvus brachyrhynchos	3	0
	Carduelis tristis	0	0.5
	Setophaga ruticilla	3	3
	Turdus migratorius	2	5
	Icterus galbula	1	0
	Mniotilta varia	5	3
	Poecile atricapilla	2	4
	Dendroica fusca	3	3
	Dendroica striata	12	13

	Dendroica caerulescens	17	8
	Dendroica virens	9	8
	Cyanocitta cristata	1	3
	Certhia americana	0	1
	Molothrus ater	1	1
	Wilsonia canadensis	15	6
	Bombycilla cedrorum	1	0.5
	Chaetura pelagica	1	0
	Spizella passerina	0	1
	Geothlypis trichas	1	0.5
	Dendroica pensylvanica	3	3
	Picoides pubescens	0	0.5
	Catharus minimus	1	0.5
	Regulus satrapa	1	0.5
	Picoides villosus	0	0.5
	Catharus guttatus	7	9
	Dendroica magnolia	11	11
	Seiurus aurocapillus	21	6
	Dryocopus pileatus	0	0.5
	Carpodacus purpureus	4	5
	Vireo olivaceus	17	6
	Sitta canadensis	2	2
	Agelaius phoeniceus	0	0.5
	Pheucticus ludovicianus	1	0.5
	Piranga olivacea	1	0
	Junco hyemalis	25	29
	Vireo solitarius	3	0.5
	Catharus ustulatus	24	4
	Troglodytes troglodytes	6	3
	Zonotrichia albicollis	22	14
	Sphyrapicus varius	0	0.5
	Dendroica coronata	15	32
	Cathartes aura	8	3
	Pandion haliaetus	13	6
	Circus cyaneus	10	0
	Haliaeetus leucocephalus	3	0
	Accipiter striatus	121	6
	Accipiter cooperii	9	6
	Accipiter gentilis	1	0
	Buteo lineatus	2	0
	Buteo platypterus	96	6
	Buteo jamaicensis	173	15
	Falco sparverius	33	0
	Falco columbarius	3	0
	Falco peregrinus	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).

Study	Ketzenberg, C., Exo, K.M., Reichenbach, M., & Castor, M. (2002). Einfluss von Windkraftanlagen auf brütende Wiesenvögel. *Natur und Landschaft* **77**: 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: Charadriformes. 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^2, Bassens 7.35 km^2, Georgshof 1.38 km^2, Leer 0.74 km^2. 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	Treatment	control	Treatment	control	Treatment	control	Treatment	control
Haematopus ostralegus	0.27	0.27	0.12	0.08	0.22	0	0.34	0.2
Vanellus vanellus	1.17	1.46	0.34	0.19	1.23	1.01	0.90	1.66
Tringa totanus	0.20	0.09	0.07	0.05	0	0.14	0.09	0.17
Limosa limosa	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 *Alauda arvensis* 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.

Study	Larsson, A. K. (1994). The Environmental Impact from an Offshore Plant. Wind Engineering **18**: 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^2. Site management techniques: unknown. Timescale: 1 year after first operation.

<table>
<tr><td rowspan="8">Outcome (Abundance)</td><td colspan="3">Mean count of bird number (n=3, sd based on the three replicates in treatment and control)</td></tr>
<tr><td></td><td>Treatment</td><td>Control</td></tr>
<tr><td>Cygnus olor</td><td>0.8</td><td>3.4</td></tr>
<tr><td>Tadorna tadorna</td><td>1.6</td><td>2.6</td></tr>
<tr><td>Anas platyrhynchos</td><td>1.7</td><td>3.4</td></tr>
<tr><td>Somateria mollissima</td><td>0.3</td><td>8.4</td></tr>
<tr><td>Clangula hyemalis</td><td>10.2</td><td>21.6</td></tr>
<tr><td>Mergus serrator</td><td>0.8</td><td>3.9</td></tr>
<tr><td>Study design</td><td colspan="3">Site comparison: 40</td></tr>
<tr><td>Baseline Comparison</td><td colspan="3">Control and treatment sites similar at baseline with respect to abundance, functional type, location habitat and size of area: 6</td></tr>
<tr><td>Intra treatment variation</td><td colspan="3">Replicates comparable and equal with respect to all specified factors:5</td></tr>
<tr><td>Measurement of Co-interventions</td><td colspan="3">Site management unreported: 0</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="3">Well replicated objective parameters of abundance: 4</td></tr>
<tr><td>Attrition bias</td><td colspan="3">No losses to follow up: 2</td></tr>
<tr><td>Sum of Data quality</td><td colspan="3">57</td></tr>
<tr><td>Notes</td><td colspan="3">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.</td></tr>
</table>

<table>
<tr><td>Study</td><td colspan="3">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. Bird Study 40: 140-143.</td></tr>
<tr><td>Methods</td><td colspan="3">Site comparison</td></tr>
<tr><td>Population and co-intervention</td><td colspan="3">Functional type of birds: Anseriformes, Charadriformes 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^2.
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</td></tr>
<tr><td rowspan="4">Outcome (Abundance)</td><td>Mean no pairs per year (n=9, se presented)</td><td>Treatment (burgar hill)</td><td>Control (sleet moss)</td></tr>
<tr><td>Anseriformes (mainly Anas Penelope, Anas, crecca, Anas platyrhynchos)</td><td>9.2 (se 3.6)</td><td>4.6 (se 4.5)</td></tr>
<tr><td>Charadriformes (Calidris alpina, Pluvialis apricaria)</td><td>25 (se 2)</td><td>15.7 (se 2.4)</td></tr>
<tr><td>Passeriformes (Alauda arvensis, Oenanthe oenanthe, Saxicola torquata, Carduelis flavirostris)</td><td>25.4 (se 2.4)</td><td>50.1 (se 1.5)</td></tr>
<tr><td>Study design</td><td colspan="3">Site comparison: 40</td></tr>
<tr><td>Baseline Comparison</td><td colspan="3">Heterogeneity with respect to species abundance, type and habitat. Location and size similar: 2</td></tr>
<tr><td>Intra treatment variation</td><td colspan="3">No information on spatial variation within replicates : 0</td></tr>
<tr><td>Measurement of Co-interventions</td><td colspan="3">Site management not equal: 0</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="3">Well replicated objective parameter of abundance used within treatment and control: 4</td></tr>
<tr><td>Attrition bias</td><td colspan="3">No losses to follow up: 2</td></tr>
<tr><td>Sum of Data quality</td><td colspan="3">48</td></tr>
<tr><td>Notes</td><td colspan="3">Cites uncaptured reference as containing abundance data: Winkelman, J.E. (1990) Verstoring</td></tr>
</table>

	van vogels door de Sepproefwindcentrale 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.

Study	Phillips, J. F. (1994). *The effects of a windfarm on the upland breeding bird communities of Bryn Titli, mid-Wales: 1993-1994*. Newtown, RSPB.
Methods	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.
Population and co-intervention	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 *Calluna* dominated moorland (H10/12?). Size of area: Windfarm area 6 km^2 (control area is adjacent 8 km^2). Site management techniques: The turbines are located on sheep walk (U5?). Timescale: 1 year since operation.

Outcome (Abundance)	Mean no of pairs per Km^2 (ntreatment=6, ncontrol=8).	Treatment (wf 94)	Control (94)
	Anas platyrhynchos	0	0.25
	Buteo buteo	0.5	0.875
	Falco tinnunculus	0	0.125
	Falco peregrinus	0.16666667	0
	Turdus merula	2	1.625
	Sylvia atricapilla	0.33333333	0.25
	Parus caeruleus	1.33333333	1.125
	Pyrrhula pyrrhula	0	0.625
	Corvus corone	0.33333333	0.5
	Fringilla coelebs	7.66666667	6.875
	Parus ater	0.16666667	0.625
	Prunella modularis	0.33333333	0.625
	Sylvia borin	1	0.125
	Regulus regulus	0.66666667	1
	Carduelis carduelis	0.33333333	0.25
	Parus major	1.16666667	0.5
	Carduelis chloris	0	0
	Motacilla cinerea	0.16666667	0.125
	Passer domesticus	0.33333333	0
	Corvus monedula	0.16666667	0.25
	Garrulus glandarius	0.16666667	0.125
	Carduelis cannabina	1.5	3.25
	Aegithalos caudatus	0.16666667	0.125
	Pica pica	0.66666667	0.625
	Parus palustris	0	0.125
	Anthus pratensis	35.6666667	44.75
	Turdus viscivorus	0.33333333	0.25
	Oenanthe oenanthe	1.16666667	1.5
	Sitta europaea	0	0.125
	Ficedula hypoleuca	0.5	1.125
	Motacilla alba	1	1
	Corvus corax	0.5	0
	Carduelis flammea	1	1
	Phoenicurus phoenicurus	3.33333333	2
	Emberiza schoeniclus	0.16666667	0.125

	Erithacus rubecula	5.33333333	2.5
	Corvus frugilegus	0	0
	Carduelis spinus	0	0.5
	Alauda arvensis	15.1666667	14.875
	Turdus philomelos	1.5	0.75
	Muscicapa striata	1	0.5
	Sturnus vulgaris	0	0.125
	Saxicola torquata	0.33333333	0
	Hirundo rustica	0.16666667	0.125
	Certhia familiaris	0.16666667	0.25
	Anthus trivialis	1.66666667	1.375
	Saxicola rubetra	3.66666667	5.375
	Sylvia communis	0	0.125
	Parus montanus	0.16666667	0
	Phylloscopus trochilus	6.83333333	6.125
	Phylloscopus sibilatrix	0.16666667	0.25
	Troglodytes troglodytes	5.16666667	4.75
	Emberiza citrinella	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^2 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^2 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.		

Study	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 *Pinus ponderosa*. 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
	Branta canadensis	0	0.004
	Anas platyrhynchos	0.013	0
	Cathartes aura	0.013	0.016
	Circus cyaneus	0.027	0.027
	Aquila chrysaetos	0.004	0.011
	Haliaeetus leucocephalus	0	0.007
	Buteo jamaicensis	0.062	0.069

	Buteo lagopus	0.004	0.013
	Buteo regalis	0.004	0.016
	Falco sparverius	0.160	0.078
	Falco mexicanus	0.004	0.002
	Falco peregrinus	0.004	0
	Sayornis saya	0.031	0.011
	Tyrannus verticalis	0	0.004
	Pica hudsonia	0.053	0.049
	Corvus corax	0.013	0.076
	Eremophila alpestris	0.022	0.360
	Petrochelidon pyrrhonota	0.018	0.142
	Hirundo rustica	0.009	0.042
	Sialia currucoides	0	0.022
	Turdus migratorius	0	0.002
	Sturnus vulgaris	0.067	0.027
	Pipilo chlorurus	0.004	0
	Pipilo maculatus	0	0.002
	Spizella passerina	0	0.002
	Chondestes grammacus	0	0.04
	Ammodramus savannarum	0.04	0.06
	Calamospiza melanocorys	0	0.002
	Passerculus sandwichensis	0	0.002
	Pooecetes gramineus	0.751	1.022
	Guiraca caerulea	0	0.002
	Sturnella neglecta	0.853	0.776
	Agelaius phoeniceus	0.004	0.042
	Quiscalus quiscula	0.022	0.000
	Euphagus cyanocephalus	0.000	0.009
	Molothrus ater	0	0.016
	Icterus bullockii	0	0.002
	Carduelis tristis	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.		

Study	Still, D., B. Little, et al. (1996). *The effect of wind turbines on the bird population at Blyth harbour.* [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^2. 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)
	Somateria mollissima	39	98
	Calidris maritima	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). *Continuation of bird studies at Blyth Harbour Wind Farm and the implications for offshore wind farms*. 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. *Wind Energy Conversion 1996***:** 175-183. and Still, D. (1994). *The birds of Blyth Harbour. Proceedings of 16th BWEA conference, Stirling, UK*. 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. Wind Energy Conversion 1996**:** 175-183. Little, B. (undated). *The effect of wind turbines on bird populations in Blyth Harbour*. Northumberland Birds?		

Study	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, Charadriformes, 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^2. 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
	Anas platyrhynchos	24.536633	346.8967
	Fulica atra	0.0665	254.60017
	Vanellus vanellus	15.392233	520.6411
	Pluvialis apricaria	10.533533	630.46647
	Numenius arquata	0.5584333	114.6749
	Sturnus vulgaris	84.715867	647.0508
	Anas penelope	0.37125	277.87875
	Aythya fuligula	0	8.3125
	Haematopus ostralegus	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.

Study	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, Charadriformes. 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
	Anas platyrhynchos	2.52	3.766667
	Aythya ferina	0.233333	0.9
	Aythya fuligula	0.733333	1.6
	Aythya marila	52.7	9.3
	Bucephala clangula	0.875	2.225
	Fulica atra	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 *Anser fabilis* and *Anser albifrons* after windfarm construction than before but that *Branta leucopsis* 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 *et al.* (2004)	12 species of Passeriformes.	11 species are more abundant in the Wind Farm area than the control area. (abundance expressed as nests/km^2). *Emberiza cia* (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 *et al.* (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). *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.).
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). *Renewable Energy and Environmental Impacts in the UK: Birds and Wind Turbines*. London, University College London.
Winkelman (1989)	Anseriformes	*Anser fabilis* and *Anser albifrons* are more abundant after windfarm construction than before but *Branta leucopsis* 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).

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

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

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

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

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

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

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

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

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