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WHAT IS THE IMPACT OF PUBLIC ACCESS ON THE BREEDING SUCCESS OF GROUND-NESTING AND CLIFF-NESTING BIRDS?

Systematic Review

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1. SUMMARY

1.1 Background

The Countryside and Rights of Way Act 2000 (CRoW), which came into effect in 2005, has created a statutory right of access to open country and registered common land in England and Wales, extending the public's ability to enjoy the countryside by opening up previously out-of-bounds areas. Scotland has similarly formalised access recently through the Land Reform (Scotland) Act 2003. However, public access (both in the UK and elsewhere) may have potentially deleterious impacts on habitats and associated flora and fauna, including species of conservation concern. Within the CRoW Act there is provision for the relevant authority to exclude or restrict access for the purpose of conserving flora, fauna, geological or physiographical features of the land in question. One particular concern and the focus of this systematic review, is the impact of human disturbance on breeding success of ground-nesting and cliff-nesting birds. It was considered that a systematic review would assist in evidence-based decision-making regarding the restriction of access for conservation purposes.

1.2 Objectives

To assess the impact of public access on foot (including associated activities i.e. dog-walking, picnicking, birdwatching, cross-country running, climbing, angling, mountain biking and horse riding) on breeding success of ground-nesting and cliff-nesting birds.

1.3 Search strategy

Relevant studies were identified through searches of the following 12 electronic databases: Agricola, Copac, Digital Dissertations Online, Directory of Open Access Journals, English Nature's "Wildlink", Europa, Index to Theses Online (1970-present), ISI Web of Knowledge, JSTOR, Science Direct, Scirus and Scopus. Searches were undertaken on conservation and statutory organisation websites: Agricultural Development and Advisory Service (ADAS); Countryside Council for Wales (CCW); Department of Agriculture and Rural Development (DARD); Department of Environment, Food and Rural Affairs (DEFRA); English Nature (EN) (now Natural England); Joint Nature Conservation Committee (JNCC); National Trust (NT); Royal Society for the Protection of Birds (RSPB); and Scottish Natural Heritage (SNH). Bibliographies of traditional literature reviews and articles accepted into the systematic review at the full text stage were examined for studies that had not yet been identified by any other means. Subject experts were contacted.

1.4 Selection criteria

The criteria which studies had to meet for inclusion into the final stage of the systematic review were:

1. *Subject*: breeding ground-nesting and cliff-nesting birds;
2. *Intervention*: human activities of walking (including dog-walking), picnicking, birdwatching, crosscountry running, angling, climbing, mountain biking and horse -riding;
3. *Outcome*: primary outcomes were changes in breeding abundance/density and population effects (population size increase or decrease);
4. *Type of study*: any field/empirical study.

1.5 Main results

The searching of electronic databases and the internet produced 14,717 articles (Table 1). After duplicates were removed, a total of 4,904 unique articles remained for assessment at title and abstract stage, of which 173 were potentially relevant and required full text assessment against the study inclusion criteria. Full text assessment yielded a total of 85 articles that were relevant for inclusion within the systematic review. Of these, 27 had quantitative data (regarding the impact of public access and associated disturbance on breeding success of ground-nesting and cliff-nesting birds) suitable for meta-analysis but only 20 provided comparable data. A total of 42 independent data points presented data regarding the subject area of which 38 could be used for meta-analysis. Four data points were dropped due to heterogeneity in the scope of study, lack of comparators and lack of estimates of variance.

Of the meta-analyses that could be undertaken sample sizes were severely limited, primarily due to the lack of comparable quantitative data presented in studies. Those undertaken indicate that hatching success and pre-fledgling survival are both significantly reduced by human disturbance (although the latter outcome was skewed by findings of one study and thus must be interpreted accordingly). There is no significant overall effect on chick weight or fledgling success.

There is significant unexplained heterogeneity between studies and species for all the outcomes examined. The period in the breeding cycle when disturbance occurs; the type and intensity of disturbance; increased predation when attending adult birds are driven from eggs and/or young; the habitat, and degree of habituation to people have all been suggested as potential reasons for variability in avian response to disturbance. Small sample sizes confounded attempts to derive quantitative relationships between these explanatory covariates and effect.

Taking into account findings of many other (mostly observational) studies subject to review but which could not be incorporated into the meta-analysis, there is limited evidence for reduced hatching and fledging success due to human disturbance on foot (including with associated pet dogs) for some species.

Narrative synthesis shows that the few studies that have investigated the effects of human disturbance on breeding densities of ground-nesting bird species, indicate that breeding density (e.g. of common ringed plover *Charadrius hiaticula*, Eurasian golden plover *Pluvialis apricaria*, dunlin *Calidris alpina*, European nightjar *Caprimulgus europaeus* and woodlark *Lullula arborea*) is substantially reduced by recreational disturbances. Such reduced breeding density, or lack of breeding success within otherwise potentially suitable habitat (the latter as yet unproven), may be the main consequence of human disturbance.

There is little quantitative evidence to draw any firm conclusions regarding cliff-nesting species, but those few studies looking at impacts of human disturbance on breeding success of cliff-nesting birds suggest a negative impact on breeding success.

1.6 Reviewers' conclusions

Implications for conservation

Evidence from quantitative studies (i.e. that subject to meta-analysis) for the impact of public access on breeding success is ambiguous (primarily due to small sample sizes). Qualitative/observational evidence derived from many other studies suggests that human disturbance through access on foot can be detrimental to the breeding success of ground-nesting birds at all stages of the breeding cycle from territory establishment to fledging. There are exceptions however, e.g. several species of penguins (Spheniscidae) and two species of tern (Sternidae). The design and reporting of the qualitative/observational studies leaves this evidence highly susceptible to bias.

A small number of mostly observational studies suggest that responses to a walker with a dog tended to be stronger than a person approaching without one; displacement of incubating or brooding birds led to increased predation risk from opportunistic predators, especially larger gulls *Larus* spp. and corvids *Corvus* spp.

The level of impact is highly variable between species and dependent upon locality and the disturbances involved. As such, proposed restrictions on access must take into account sensitivity and vulnerability to disturbance on a *species by species* basis, and site characteristics. There is insufficient evidence to draw any firm conclusions specifically regarding cliff-nesting species, but that which is available suggests a negative impact of human disturbance upon breeding success of a small number of species for which studies have been undertaken.

Implications for further research

There is much scope for further investigation into the effects of human disturbance on the breeding success of ground-nesting and cliff-nesting birds. Although there have been many studies looking at the effects of disturbance, few have robust quantitative data regarding impacts on breeding success and populations. Evidence given frequently stems from *ad hoc* observations rather than from rigorous, structured field research. A number of studies simply infer that a detrimental impact is presumed, or evidence presented is anecdotal. Some lack suitable controls, whilst in others disturbance levels (or treatments) are not well assessed or are poorly defined. Especially useful would be longer term studies investigating the consequences of disturbance impacting at the population level, of which to date very few ecologists have tackled. The role of recreational disturbance in reducing breeding bird densities (and potential site-scale desertion) could usefully be further addressed. It is evident that for some species the degree of habituation to people may be an important factor governing breeding success; this could also therefore be a topic of further research.

2. BACKGROUND

The Countryside and Rights of Way Act 2000 (CRoW), which came into effect in 2005, has created a new statutory right of access to open country (mountain, moor, heath, down and registered common land, including wetlands and coastal areas) in England and Wales, extending the public's ability to enjoy the countryside by opening up previously restricted areas (HMSO 2000). Scotland has similarly formalised access recently through the Land Reform (Scotland) Act 2003, which establishes a statutory right of responsible access to land and inland waters for outdoor recreation and crossing land (HMSO 2003). However, public access may have potentially deleterious impacts on habitats and species, some being of special conservation concern in the UK, including several species of ground-nesting birds e.g. black grouse *Tetrao tetrix* (Yalden 1986, Baines & Richardson 2007), western capercaillie *Tetrao urogallus* (Marshall 2005), common ringed plover *Charadrius hiaticula* (Liley 1999, Liley & Sutherland 2007), Eurasian golden plover *Pluvialis apricaria* (Yalden & Yalden 1989, 1990), Eurasian stone-curlew *Burhinus oedicnemus* (Taylor 2007), European nightjar *Caprimulgus europaeus* (Liley & Clarke 2002, 2003, Murison 2002, Woodfield & Langston 2004a) and woodlark *Lullula arborea* (Mallord 2005). Within the CRoW Act, there is provision for the relevant authority (Countryside Council for Wales – Wales; Natural England (formerly English Nature) – England) to exclude or restrict access for the purpose of conserving flora, fauna or geological or physiographical features of the land in question (HMSO 2000).

Yet, the passage of the CRoW Act highlighted the lack of suitable information to guide bird conservation measures in response to this increased access (Liley 2002). In order to help bridge this gap, relevant information on the impact on bird populations of disturbance arising from human access on foot (including with dogs) was collated in a literature review undertaken by the RSPB (Woodfield & Langston 2004b). This substantial report highlighted the relative scarcity of information concerning effects of disturbance specifically upon breeding success and bird populations, and identified the need for more, scientifically robust, disturbance

studies. In light of this and earlier recommendations, around this time a few such research projects e.g. on woodlark (Mallord 2005) and Eurasian stone-curlew (Taylor 2007), were undertaken. Subsequently, several UK governmental and non-governmental stakeholder organisations in consultation with the Centre for Evidence-based Conservation (CEBC) identified the need for an independent systematic review incorporating information from these and other relevant studies in order to assist in policy formulation and management guidance. In addition, representatives from a wide range of UK governmental and non-governmental organisations recognised the impacts of recreational activities on biodiversity as one of the top 100 questions that needed to be answered in order to formulate evidence-based policy (Sutherland *et al.* 2006). With regards birds, of particular concern are the effects of human disturbance on breeding ground-nesting and cliff-nesting species. This is in part due to the type of countryside being opened up where many ground- and cliff-nesters typically breed, but also their apparent vulnerability to disturbance and that species of conservation concern are liable to be impacted.

This review focuses specifically on the impact of public access on foot and associated activities (i.e. dog-walking, picnicking, bird-watching, cross-country running, climbing, angling, mountain -biking and horse riding) on breeding success of ground-nesting and cliff-nesting birds. As well as disturbance studies within the UK, all those potentially relevant from around the world, regardless of species, were considered for inclusion into the review. This was considered appropriate on the basis that: outcomes of studies are potentially applicable to closely related taxa occupying similar habitats elsewhere; compilation of as much information as possible was deemed to give the best overall assessment of impacts; incorporating studies on a global scale gives the review a wider perspective and thus relevance to a broader audience beyond the UK.

This review is therefore designed to be relevant particularly in relation to decisions about the application of the access clauses of the CRoW Act, whilst having a wider international relevance for other practitioners and policy makers regarding management of areas subject to human disturbance. It is also hoped that it will highlight gaps in research and assist in the formulation of informative research projects.

3. OBJECTIVES

To systematically collate and synthesise published and unpublished material in order to assess the impact of public access on foot, including associated activities (i.e. dog-walking, picnicking, bird-watching, cross-country running, climbing, angling, mountain -biking and horse riding) on breeding success of ground-nesting and cliff-nesting birds.

4. METHODS

4.1 Question formulation

The RSPB identified the need for an impartial and independent systematic review to be undertaken to evaluate the impact of public access on breeding success of ground-nesting

and cliff-nesting birds and identify any affects at the population level**.** The specific question to be addressed was formulated through discussion between the CEBC and UK-based stakeholder organisations with an interest in the review.

4.2 Search strategy

Relevant studies were identified through computerised searches of the following 12 electronic databases:

- ISI Web of Knowledge
- Science Direct
- Directory of Open Access Journals (DOAJ)
- Copac
- Scirus
- Scopus
- Index to Theses Online (1970-present)
- Digital Dissertations Online
- Agricola
- Europa
- English Nature's "Wildlink"
- JSTOR

The search terms used were:

- Bird* AND access*
- Bird* AND trampling*
- Bird* AND recreation*
- Bird* AND walk*
- Bird* AND disturbance*
- Human AND disturbance*
- Human AND activity

Publication searches were undertaken on conservation and statutory organisation websites: Agricultural Development and Advisory Service (ADAS); Countryside Council for Wales (CCW); Department of Agriculture and Rural Development (DARD); Department of Environment, Food and Rural Affairs (DEFRA); English Nature (EN); Joint Nature Conservation Committee (JNCC); National Trust (NT); Royal Society for the Protection of Birds (RSPB); and Scottish Natural Heritage (SNH). Google searches for reports for some species and families were also undertaken.

Bibliographies of articles accepted into the systematic review at the full text stage and traditional literature reviews were searched for studies that had not yet been identified by any other means. Recognised experts and practitioners were contacted and asked to

recommend any additional sources of potentially relevant information. Foreign language searches were not conducted. However, the search identified studies on a global scale, all of which were included in the systematic review process.

4.3 Study inclusion criteria

Studies were initially filtered by title and any obviously irrelevant articles were excluded. Subsequently, the abstracts of the remaining studies were examined with regard to possible relevance to the systematic review question. Of these articles (n = 173) 54% were assessed for relevance by a second independent reviewer; agreement on inclusion between the reviewers was deemed to be "almost perfect" (Cohen's Kappa test: K = 0.864). Studies were accepted for viewing at full text if it appeared that they may contain information pertinent to the review or, if the abstract was ambiguous (or lacking) and thus did not allow inferences to be drawn about the article content. The criteria which studies had to meet for inclusion into the final stage of the review were:

1. *Subject:* breeding ground-nesting and cliff-nesting bird species;
2. *Intervention:* walking, dog-walking bird-watching, cross-country running, picnicking, angling, climbing, mountain-biking, horse-riding, versus no access or access at a lesser intensity;
3. *Outcome:* the primary outcome was change in abundance of bird species, and population effects. Secondary outcomes concerned local effects (e.g. breeding success and displacement from breeding habitat). However, studies were not rejected on the basis of outcome;
4. *Type of study:* any empirical/field study with appropriate treatments and controls were included in the quantitative synthesis. All other relevant studies were included in a narrative synthesis.

Studies accepted into the review at full text were considered for relevance by two reviewers. Any disagreement on inclusion was discussed and resolved by consensus.

Studies not included:
This review specifically investigates the impact of human disturbance (and associated pet dogs *Canis lupus familiaris*) through access on foot on breeding success of ground-nesting and cliff-nesting birds, and associated impacts at the population level. Therefore excluded disturbance studies included:

1. Studies outside the breeding season (e.g. effects of disturbance during migration or on wintering grounds);
2. Studies looking at flushing and or/alert distances of birds upon approach of a human and/or dog, unless undertaken in the breeding season and inferences on breeding success are discussed;
3. Studies looking at disturbance or predation by feral dogs.

4.4 Study quality assessment

A single reviewer (DS) considered articles viewed at full text and studies with appropriate designs (studies presenting quantitative data with comparators and variance measures or binomial data) were included in quantitative syntheses. Summaries of methodology (e.g. study design, timescale, outcomes) were tabulated (Appendix 1). Other studies for which data could not be included in meta-analysis due to lack of data comparability with others, and observational/anecdotal studies, are narratively summarised (Appendix 2).

4.5 Data extraction

Where means and variance measures were available, standardised mean effect sizes were calculated using Hedges d (Deeks *et al.* 2001). Binary data were used to generate risk ratio effect size metrics (Cooper & Hedges 1994, Deeks *et al.* 2001). Multiple effect sizes were generated from single studies which presented data on more than one species. Missing variance was imputed using average values in the pre-fledgling survival and fledgling success analyses. Data extraction was performed by two reviewers (DS and GS). Reported outcomes are listed in the form of narrative summaries where qualitative data, quantitative data without comparators, and data regarding outcomes other than change in population or abundance of the bird species in question are presented (Appendix 2).

4.6 Data synthesis

The impact of disturbance was explored using meta-analysis and meta-regression (Cooper & Hedges 1994, Scheiner & Gurevich 2001, Deeks *et al.* 2001). These analyses were performed on hatching success, pre-fledging survival, chick weight at fledging and fledging success. Data were pooled and combined across studies using DerSimonian and Laird random effects meta-analysis based on standardised mean difference (SMD) (DerSimonian & Laird 1986, Cooper & Hedges 1994). The random effects model anticipates that the true effect size differs among studies and the aim of the analysis is to quantify such variation in the effect parameters; it is therefore appropriate for ecological questions where the true effect is likely to vary between studies (Gurevitch & Hedges 1999).

Hedge's d effect sizes (Deeks *et al.* 2001) were derived from the treatment and control means, standard deviations and sample sizes to calculate standardised mean differences. The standardised mean difference method expresses the size of the treatment effect in each study relative to the variability observed in that study (Deeks *et al.* 2001) allowing combination of the different bird disturbance parameters reported in the primary studies. Where continuous data were not presented binary data were analysed using risk ratios combined in a random effects model using the method of DerSimonian & Laird, with the estimate of heterogeneity being taken from the Mantel-Haenszel model (Deeks *et al.*

2001). The impact of disturbance on hatching success, pre-fledging survival, chick weight at fledging and fledging success was examined by inspection of forest 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 & Sharp 1999). A forest plot is a graphical display illustrating the relative strength of treatment effects in multiple quantitative studies addressing the same question (Lalkhen & McCluskey 2008).

4.7 Taxonomy and names

Scientific bird names follow those of the IOC World Bird Names online database (Gill & Donsker 2010). Recent taxonomic changes which differ from those of the original studies are as follows:

Herring gull *Larus argentatus* (in Hunt 1972) formerly treated as *Larus argentatus smithsonianus* is elevated to full species status, American herring gull *Larus smithsonianus*;

Snowy plover *Charadrius alexandrinus nivosus* (in Ruhlen *et al*. 2003, and Lafferty *et al*. (2006) is elevated to full species status, *Charadrius nivosus*;

Bridled tern *Sterna anaethetus* (in Gyuris 2004) becomes *Onychoprion anaethetus*

Vernacular names mostly follow IOC names, exceptions being: common guillemot (rather than common murre) *Uria aalge* and Arctic skua (rather than parasitic jaeger) *Stercorarius parasiticus*, which are retained as the IOC English names are rarely used in the UK. Red grouse is retained for *Lagopus lagopus scoticus* the British race of willow grouse *L. l. lagopus* (rather than willow ptarmigan, as this IOC English name will be unknown to many readers).

5. RESULTS

5.1 Description of studies

Searching was completed in March 2007; 14,716 articles were captured using electronic database searches and a small number via other sources. 173 articles remained in the systematic review after the abstract filter stage (Table 2). Much general information relevant to the review question was present on conservation and statutory organisation websites but none viewed contained data suitable for meta-analysis.

A total of 173 articles were accepted into the final stages of the systematic review, with 85 remaining after full text filter. Of these 27 had quantitative data suitable for meta-analysis (these studies are summarised in Appendix 1), however, only comparable

information from 20 of these (38 data points) were appropriate for quantitative synthesis. Only two studies provided quantitative data regarding the impact of human disturbance on cliff-nesting species.

Table 1. Number of articles included during each of the systematic review filtering stages.

Systematic review stage	**No. of articles**
Studies captured using search terms in electronic databases (including duplicates)	14,717
Studies captured using search terms in electronic databases (excluding duplicates)	*4,904
Studies remaining after title filter	419
Studies remaining after abstract filter	173
Studies remaining after full text filter	85
Studies used in meta-analysis	20

* approximate figure

5.2 Quantitative synthesis

Data were divided into four broad categories for which there was sufficient data to perform meta-analysis: hatching success; chick weights; pre-fledgling survival; and fledging success.

5.2.1 Hatching success

In five of the six studies (American herring gull *Larus smithsonianus*, Hunt 1972; common ringed plover, Pienkowski 1984; hooded dotterel *Thinornis rubricollis*, Dowling & Weston 1999; and common ringed plover, Liley 1999, Baines & Richardson 2007) hatching success was greater in less disturbed compared to more disturbed areas. Conversely, Yalden (1992) found that hatching success was higher in common sandpiper *Actitis hypoleucos* territories with more people (71%) than stretches with fewer people (58%), though the differences are not significant (Table 2). Meta-analysis illustrates significant heterogeneity between studies/species (Chi-squared 20.59, d.f. = 6, p = 0.003 but overall disturbance significantly reduces hatching success (pooled risk ratio 1.619, 95% CI 1.246 to 2.104, z= 3.61 p <0.001, Figure 1).

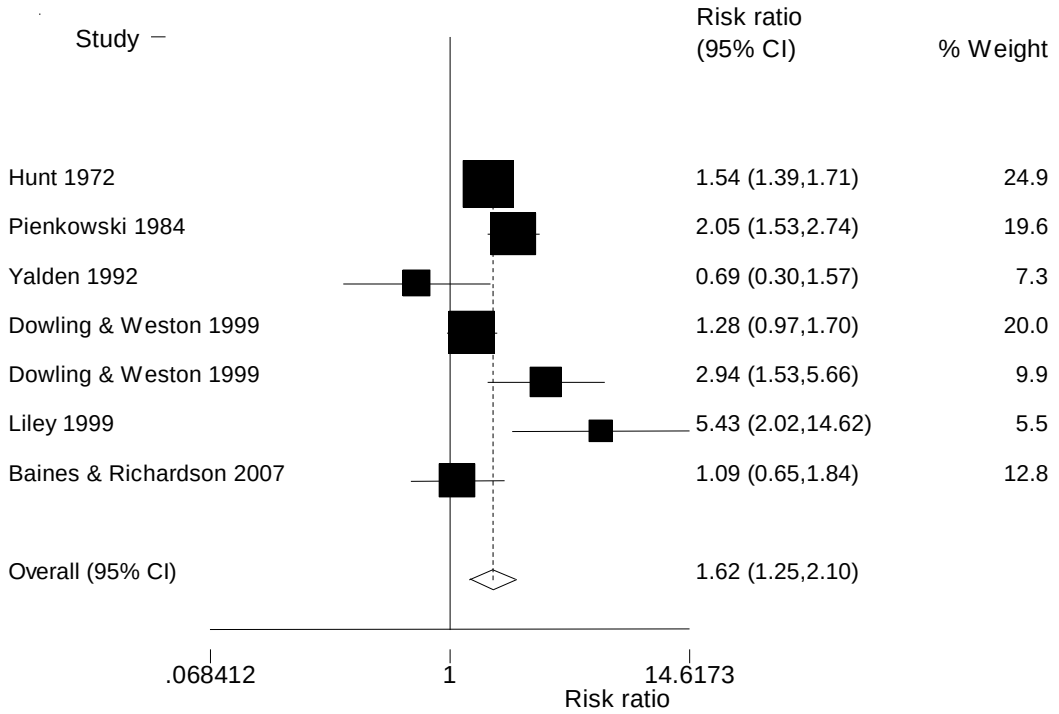

Figure 1. Forest plot of hatching success (disturbed compared with control, or less disturbed areas) effect sizes. Solid boxes represent the effect size of individual studies; box size is related to sample size; error bars are 95% confidence intervals; the open diamond is the pooled effect sizes generated using standardized mean difference random effects meta-analysis. In this case a risk ratio of >1 indicates a decrease in hatching success. (See Table 2, for species to which each of the studies refers).

Table 2. Proportion of nests hatching in more disturbed, compared to less disturbed areas for four species of ground nesting birds.

Reference	Species	Treatment (or more disturbance)		Control (or less disturbance)		Comparison
		Number of nests	% hatching	Number of nests	% hatching	
Hunt 1972	American herring gull	375	22 (chicks hatched/ eggs laid)	483	49.5 (chicks hatched/ eggs laid)	high vs. low disturbance areas (assessed subjectively by no. of fireplaces, beer cans & picnic groups
Pienkowski 1984	Common ringed plover	55	1.7	50	50.5	high disturbance (100+ visitors/day) vs. low disturbance (c.5 visitors/day) area
Yalden 1992	Common sandpiper	[1]17	71	[1]40	58	busy (>6 people/km/visit) vs. quiet (<6 people/km/ visit) sections of shoreline
Dowling & Weston 1999	Hooded dotterel	41	24	56	41	Nests on beach (more disturbed) vs. on dunes (less disturbed)
Dowling & Weston 1999	Hooded dotterel	49	0	5	40	where dogs and people allowed (more disturbed) vs. where people allowed but not dogs (less disturbed)
Liley 1999	Common ringed plover	16	68	139	94	survival through incubation; daily nest survival rate at highest human disturbance level vs. lowest
Baines & Richardson 2007	Black grouse	33	46	22	48	no disturbance (low), vs. twice weekly disturbance (high) by walker

[1] number of territories

5.2.2 Pre-fledgling survival

Meta-analysis illustrates significant heterogeneity between species/sites (chi-squared 417.84 d.f. 4, p < 0.001). Although overall access exhibits a significant negative impact on pre-fledgling survival (DL SMD -4.04909, z 2.00, *p* 0.046, Figure 2), this significant result is due to a large negative effect found in part of a study on Adelie penguin *Pygoscelis adeliae* (Geise 1996). Within this study this finding only applied to one of the two treatment control pairs reported. It was hypothesised that variation in the duration of exposure to access was responsible for this variation but time was not significantly related to effect size (coef 0.287, se 0.401, z 0.71, *p* 0.475). Variation in pre-fledgling survival in response to access is therefore unexplained.

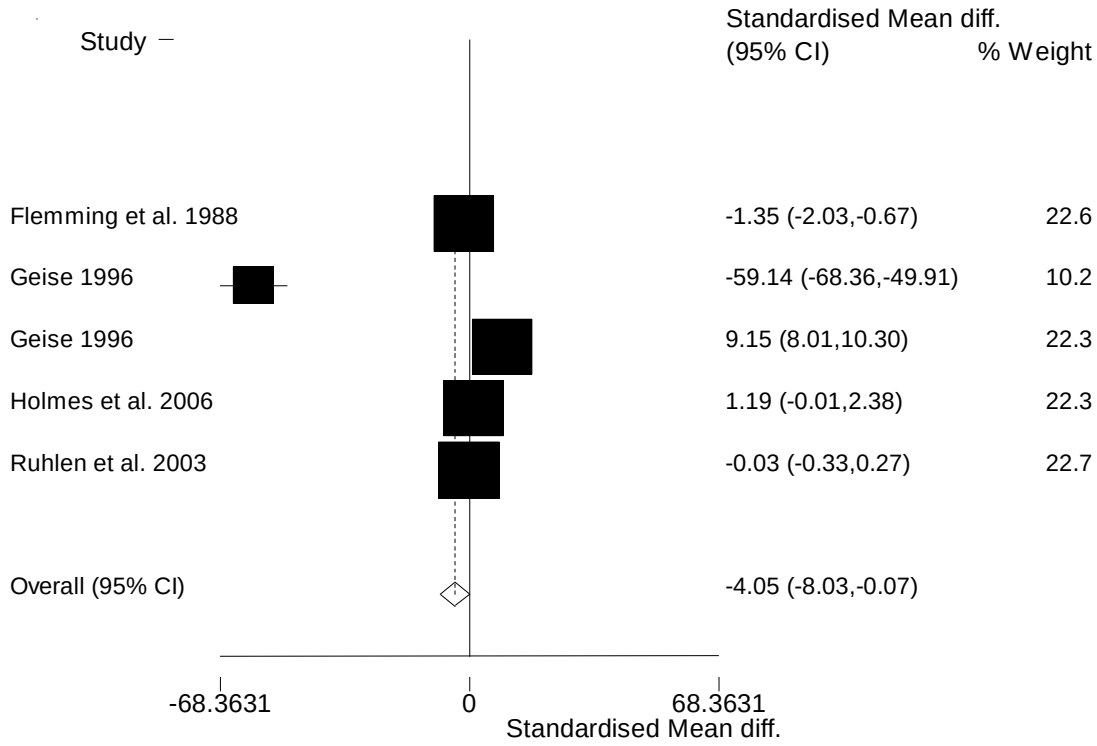

Figure 2. Forest plot of pre-fledgling survival (disturbed compared with control, or less disturbed areas) effect sizes. Solid boxes represent the effect size of individual studies; box size is related to sample size; error bars are 95% confidence intervals; the open diamond is the pooled effect sizes generated using standardized mean difference random effects meta-analysis. (See Table 3, for species to which each of the studies refers).

Table 3. Pre-fledging survival/productivity in more disturbed, compared to less disturbed areas for four species of ground nesting birds.

Reference	Species	Treatment (or more disturbance)		Control (or less disturbance)		Comparison
		N	outcome	N	outcome	
Flemming *et al.* 1988	Piping plover	18 nest attempts	1.2 chicks/ pair	24 nest attempts	1.8 chicks/ pair	no. of chicks surviving/nest attempt to 10 days old in high vs. low disturbance areas
Geise 1996	Adelie penguin	37 nests	5 nests	46 nests	31 nests	no. of nests with at least 1 chick raised to 2 weeks old; smaller colony size
Geise 1996	Adelie penguin	75 nests	62 nests	63 nests	58 nests	no. of nests with at least 1 chick raised to 2 weeks old; larger colony size
Ruhlen *et al.* 2003	Snowy plover	83	35	83	65	Cumulative percent chick survival on high (weekends/holidays vs. low disturbance (weekdays) days
Holmes *et al.* 2006	Gentoo penguin	3 colonies	1.43 chicks/ pair	46 colonies	0.9 chicks/ pair	mean breeding success (chicks reared to crèche age) on-station (high human activity, inc. some vehicular disturbance) and off-station (low human disturbance)

5.2.3 Chick weights

Meta-analysis illustrates significant heterogeneity between species/sites (chi-squared 12.58, d.f. 4, *p* 0.014); but there is no significant overall effect of disturbance on chick weights (DL SMD -0.107, z 0.45, *p* 0.650).

McClung *et al.* (2004) in a study of the effects of human disturbance on yellow-eyed penguins *Megadyptes antipodes*, clearly show a large statistically significant decrease in chick weight in disturbed sites (Figure 3). Yellow-eyed penguins appear to grow accustomed only to minimal well-regulated exposure to humans (e.g. people in hides) but remain timid where presence of unconcealed people is unpredictable at close quarters, as in this study. Presence of people may have interfered with adults bringing food to chicks, or caused chicks to move thus proving energetically costly. Whether fledging weight is a predictor of juvenile survival was investigated using long-term (1981-2000) re-sighting data. This indicates that survival probability was positively correlated with weight at fledging.

Conversely, Cobley & Shears (1999) in their study of gentoo penguins *Pygoscelis papua*, and Yorio and Boersma (1992) in a study of magellanic penguins *Spheniscus magellanicus*, show no effect of disturbance. These penguins appeared to be habituated to human visitation in colonies regularly visited by tourists, with no outward detrimental effects (based on behavioural observations) apparent. However, some studies show that some penguin species or individuals within a colony may suffer from chronic physiological stress (magellanic penguins, Walker *at al*. 2006, 2008; yellow-eyed penguins, Ellenberg *et al*. 2009) due to human visitation, that could have important effects but which are difficult to detect. Gyuris (2004) showed that bridled tern *Onychoprion anaethetus* chick weights were significantly heavier at 12-13 days old at sites exposed to higher levels of disturbance but by 21-22 days (fledging age) the difference was not significant. The effect on chick weight was however only significant in the first season of disturbance treatment but not in the second. An explanation for this was that chicks may be adversely affected by human approaches but that these affects may be ameliorated by habituation to human intrusion into nesting colonies. However, environmental variables may have played a role (food resources were poor in the first season) and it is also pointed out that there is much variation in species' habituation ability. Between species/ site variation in the meta-analysis was not related to time (coef -0.169, z -1.38, *p* 0.166) and therefore does not support amelioration of disturbance effects by habituation as an explanation of between-study variation.

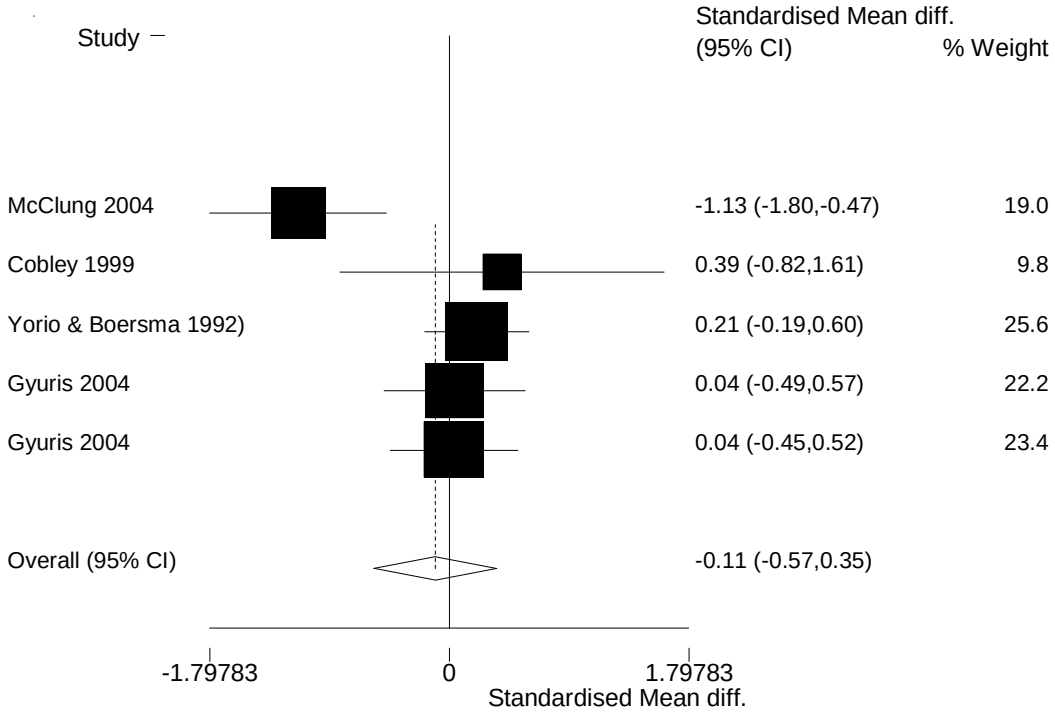

Figure 3. Forest plot of chick weights (disturbed compared with control, or less disturbed areas) effect sizes. Solid boxes represent the effect size of individual studies; box size is related to sample size; error bars are 95% confidence intervals; the open diamond is the

pooled effect sizes generated using standardized mean difference random effects meta-analysis. (See text above, for species to which each of the studies refers).

5.2.4 Fledging success

Meta-analysis illustrates significant heterogeneity between species/sites (chi-squared 2330.94, d.f. 15, p <0.001) but overall access does not have a statistically significant negative impact on fledgling success (DL SMD -0.211, z= 0.64 p = 0.525, Figure 4). Two studies illustrate a significant negative effect of human disturbance. Anderson and Keith (1980) showed that brown pelican *Pelicanus occidentalis* fledgling output was greatly reduced in breeding colonies subject to human disturbance (0.26 fledglings/pair) compared to those with no human visitation (1.33/pair). In a study of common ringed plovers, Liley (1999), found that in nesting areas with human access (eggs prone to trampling) of 36 nests, 4.6% of eggs successfully fledged; in contrast on areas of cordoned off beach (no access) of 17 nests 12.7% of eggs successfully fledged. Of other studies looking at the effect of disturbance on fledging success of 13 other species, 12 exhibited a (non-significant) detrimental trend of disturbance. Finney *et al*. (2005) whilst finding a trend towards reduced golden plover brood survival to fledging in less disturbed areas (i.e. further away from a busy moorland footpath) found no detectable impact of the levels of disturbance prevailing at the study site on reproductive performance overall (Table 4). Heterogeneity between species/ sites was not related to time (coef -0.169, z -1.38, *p* 0.166) and therefore remains unexplained.

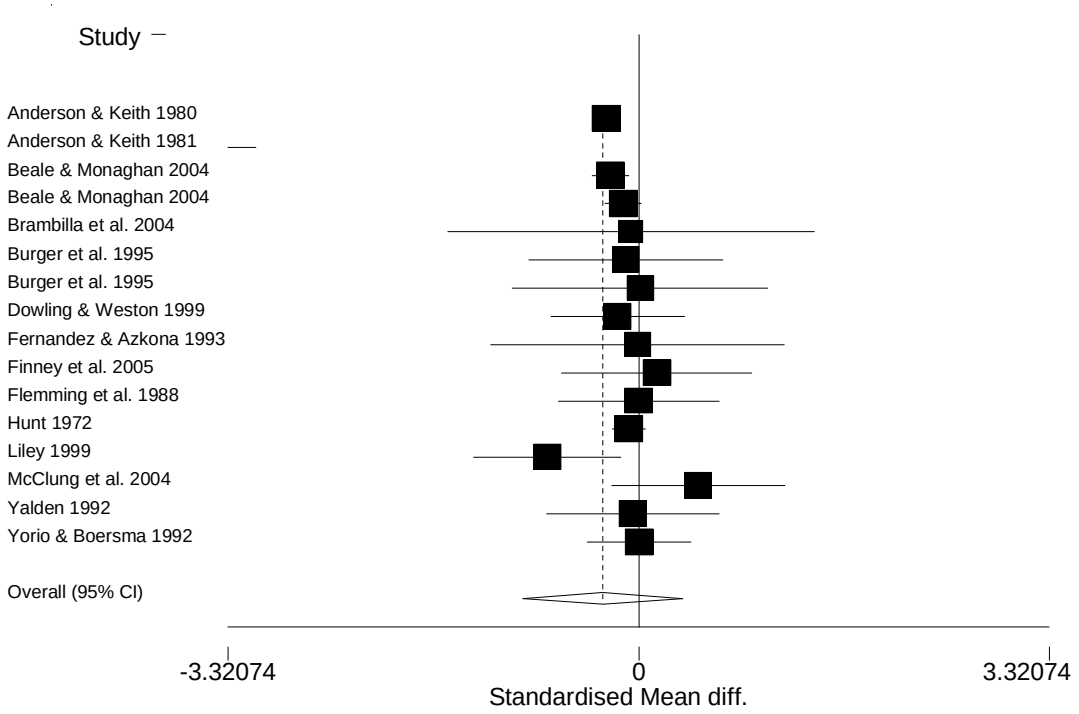

Figure 4. Forest plot of fledging success (disturbed compared with control, or less disturbed areas) effect sizes. Solid boxes represent the effect size of individual studies; box size is related to sample size; error bars are 95% confidence intervals; the open diamond is the pooled effect sizes generated using standardized mean difference random effects meta-analysis (includes studies with average substituted for missing n or sd). Data combined using random effects meta-analysis, hedges d effect sizes. (See Table 4, for species to which each of the studies refers).

Table 4. Fledging success in more disturbed compared to less disturbed areas for 15 species of ground nesting birds.

Reference	Species	Treatment (or more disturbance)		Control (or less disturbance)		Comparison
		N	outcome	N	outcome	
Anderson & Keith 1980	Brown pelican	2,663 nests	0.26 fledglings/ pair	3,328 nests	1.33 fledglings/ pair	Mean productivity (young/pair fledged) in 3 breeding seasons of nests disturbed by human visitors at egg/small young stage vs. undisturbed nests
Anderson & Keith 1980	Heerman's gull	1,281 adults	4.5 young/100 adults	1,421 adults	17.7 young/100 adults	Number of young/100 adults in sub-colonies subject to heavy vs. no known human disturbance
Beale & Monaghan 2004	Black-legged kittiwake	40% increase in visitor numbers	c.2% nesting success	50% decrease in visitor numbers	c.96% nesting success	Overall relationship (modelled) between human disturbance and nesting success. (Values for nesting success are approximate only as read off figure).

Beale & Monaghan 2004	Common guillemot	40% increase in visitor numbers	c.36% nesting success	50% decrease in visitor numbers	c.87% nesting success	Overall relationship (modelled) between human disturbance and nesting success. (Values for nesting success are approximate only as read off figure).
Brambila *et al*. 2004	Peregrine falcon	2 nests (climbers present)	50%	14 nests (no human disturbance)	79%	Nesting success (young reared to fledging) at cliff sites subject to climber disturbance only (i.e. no raven *Corvus corax* present) vs. no human disturbance
Burger *et al*. 1995	Least tern	12 colonies	29%	13 colonies	73%	Percentage of numbers of pairs raising >0.5 young/pair in more frequently disturbed colonies vs. colonies (1983-1990) with few disturbances
Burger *et al*. 1995	Least tern	13 colonies	32%	5 colonies	27%	Percentage of numbers of pairs raising 0.1-0.5 young/pair in more frequently disturbed colonies vs. colonies (1983-1990) with few disturbances
Dowling & Weston 1999	Hooded dotterel	49 clutches	0 fledged/nest	40 clutches	0.53 fledged/nest	Mean number of fledglings/clutch at nests on beach with 'least managed conditions' (i.e. walkers and their dogs (on a lead) allowed at all times vs. 'most intensive management regimes' (i.e. no dogs; Plover Watch; restricted access)
Fernández & Azkona 1993	Western marsh harrier	6 nesting pairs	64% (of 25 eggs laid, 16 chicks) fledged	5 nesting pairs	67% (of 24 eggs laid, 16 chicks) fledged	Fledging success of disturbed vs. undisturbed pairs
Finney *et al*. 2005	Eurasian golden plover	13	20%	13	10%	Brood survival to fledging (derived from model residuals of survival nearest (c.100 m) to furthest (1,200 m) from a major upland footpath
Flemming *et al*. 1998	Piping plover	16 nests	0.5 fledglings/ pair	21 nests	1.8 fledglings/ pair	Chicks surviving to fledging/nest attempt in areas of high vs. low disturbance (mean of 4 breeding seasons, 1979-83) doesn't appear correct in forest plot
Hunt 1972	American herring gull	375 nests	0.288 young fledged/nest	483 nests	0.606 young fledged/ nest	Number of young fledged/nest at gull colonies on islands subject to greater and less frequent visitor disturbance (mainly picnickers); measured subjectively on basis of 'number of old fireplaces, beer cans and picnic groups' encountered during visits
Liley 1999	Common ringed plover	36 nests	4.55	17 nests	12.64	Mean % of eggs fledged in areas with human access (eggs prone to trampling) vs. no access
McClung *et al*. 2004	Yellow-eyed penguin	19 pairs	0.95	14 pairs	0.79	Number of young successfully fledged/pair in a more disturbed vs.

						less disturbed area
Yalden 1992	Common sandpiper	23 territories	65%	12 territories	83%	Proportion of territories successfully fledging young
Yorio & Boersma 1992	Magellanic penguin	36 nests	1.06	54 nests	1.04	Breeding success (chicks fledged/active nest) in a tourist vs. non-tourist area

Assessing publication bias

To test for publication bias in the studies related to fledging success we performed Egger's test illustrated by a funnel plot (Figure 5). This suggests no evidence of publication bias. Other sample sizes were too small to perform this test and the presence or absence of publication bias is unknown.

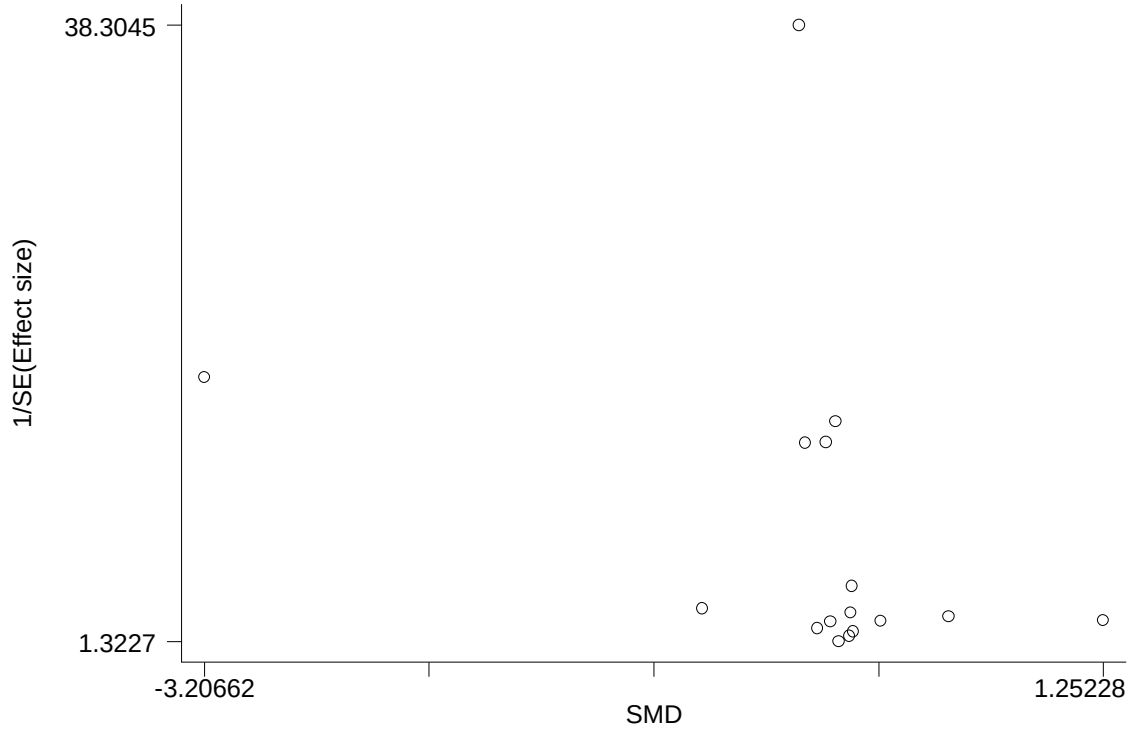

Figure 5. Funnel plot of fledging success studies to assess publication bias.

5.3 Narrative synthesis

5.3.1 Summaries of studies of human access disturbance on breeding ground-nesting and cliff-nesting birds

Summarised in Appendix 2 are the findings of relevant disturbance studies inclusive of and in addition to those included in the meta-analysis. Whilst most are specific to recreational human access disturbance, some occasional information is drawn from other sources as useful inferences may be drawn from them. For example, 'investigator disturbance' papers (which look at the effects of approaches to nests by researchers, which involve handling of eggs and/or chicks, and sometimes, adult birds) are not included in the analysis. Clearly this form of disturbance is very different to the question being addressed in this review, however, a few examples are summarised where they usefully highlight what might occur through casual visitation to the general vicinity of nests, by for example, walkers or birdwatchers.

The problem of disturbance by domestic dogs, an issue of conservation concern within its own right, is summarised in section 5.3.2. Lekking species, which face a specific and potential problem arising from human disturbance in the vicinity of lekking grounds at the onset of the breeding season, are addressed in section 5.3.3.

5.3.2 Domestic dogs and disturbance

There are many studies of the effect of human disturbance on wildlife but few look at disturbance caused by domestic dogs or try to isolate the effect of dogs from the people that normally accompany them. One review has been published (Taylor *et al.* 2005) which attempted to summarise the effects of pet dog disturbance on wild birds. It highlights how very few studies there are which examine specifically the effect of dog disturbance on breeding birds, and that much available evidence is anecdotal. This present systematic review identified some additional studies that looked at the effect of approaches of dogs *and* people on flush distances and 'alertness' of birds (both within and outside of the breeding season) but they did not attempt to separate the effect of dogs from people. An exception is Miller *et al.* (2001) which looked at human versus dog disturbance of vesper sparrow *Pooecetes gramineus* and western meadowlark *Sturnella neglecta*, but this study does not quantify the effects on breeding success. The impact on breeding success is perhaps the main issue of concern for conservationists i.e. whether dogs can influence the breeding population size that a site may be able to support (Gill *et al*. 1996).

There is only sparse evidence that dogs directly impact breeding success from a few field studies and *ad hoc* observations, mostly where very small numbers of chicks were predated by dogs e.g. killdeer *Charadrius vociferous* (Nol & Brooks 1982); common ringed plover (Liley 1999); European nightjar (Murison 2002); and snowy plover *Charadrius nivosus* (Lafferty *et al.* 2006). Hockey 1997, also reported that dogs predated chicks, and also eggs, of African oystercatcher *Haematopus moquini*.

Pienkowski (1984) recorded some losses for common ringed plovers at Lindisfarne, northeast England. Here dogs were responsible for taking one adult bird and destroying at least five clutches (with possibly three more taken by a dog, but perhaps attributable to red fox *Vulpes vulpes*) out of a total of 172 clutches over two years. Perhaps more importantly, the effect of disturbance by both people and dogs were thought to benefit carrion crows *Corvus corone*, which appeared to use vantage points to look for incubating plover movements and hence locate nests, when displaced by approaching people or dogs; corvids were the main predator responsible for 34% of clutches lost.

It has been shown that dogs will visit nests and flush incubating birds off eggs. Woodfield and Langston (2004a), using nest cameras, recorded 12 flushing events of sitting European nightjars. One was flushed by a dog once whilst incubating, and again whilst brooding, but in this case the single young fledged successfully. These and other studies, such as that of Murison 2002 (also European nightjars), have led to the general consensus that incubating birds that are flushed may betray the whereabouts of the nest and leave eggs or young vulnerable to predation. Hence the high predation rates by opportunistic predators (especially crows and larger gulls) recorded for some ground-nesting species has been attributed to dog disturbance.

A few studies have looked at the affect of human approaches with or without dogs on nesting bird behaviour (as opposed to actual breeding success). Lord *et al.* (2001) evaluated the affect of deliberate human/dog approaches to New Zealand plover *Charadrius obscurus aquilonius* nests. This study provides some of the sparse experimental evidence that nesting shorebirds perceive dogs as posing more of a threat than humans walking without a dog. Three different nest approaches (commencing at 200 m and approaching to within 5 m) were undertaken to 15 nests: walking, walking with a muzzled dog on a lead, and running (to mimic a jogger). Flush distances, time off the nest and distraction display intensity, were recorded. Of the treatments, walking with a dog caused most disruption, with incubating birds flushing earlier (mean 94 m) compared to walking/running (mean 64 m). The attending bird also remained off the nest longer (4.8 min) when approached with a dog, than without (3.4 min). Distraction display intensity appeared to be unrelated to approach type. The greater flush distances and longer time that adult plovers spent off their nests in response to a dog with a person meant that eggs were uncovered more often and for longer, possibly exposing them to increased predation risk and thermal stress.

Yalden and Yalden (1990) in their study of breeding Eurasian golden plovers found that adult birds flushed at consistently greater distances when a walker approached with a dog, than without a dog. Only 37% allowed an approach to within less than 10 m when a dog was present, whereas 68% allowed such an approach by a walker with no dog. This greater sensitivity to dogs than people was considered a cause of concern, as disturbance was daily and about 300 dogs (60% off leads) were estimated to pass through the area each breeding season. They attributed the death of three, old golden plover chicks to dogs, and in a later study at the same locality, of 22 radio-tagged chicks, two appeared to have been killed by dogs (Finney *et al.* 2004). From this very small sample, it was tentatively estimated that there was a 23% chance of a chick being killed by a dog that

would otherwise have fledged successfully, and that were dog predation eliminated the proportion of chicks fledging would rise from 21% to 27%. At this locality dogs are meant to be leashed, but over the study duration 58% were observed not to be, with 14% running across the moorland under no control. Other breeding ground-nesters here, such as dunlin, could also have been impacted.

Hoopes (1993) in a study of piping plovers *Charadrius melodus* on a Massachusetts beach (USA) found that average response distance (of birds of all ages, all behaviours) was 23 m for pedestrians (range 10 m to 60 m), but 46 m for dogs/pets (range 20 m to 100 m). Unleashed dogs may also chase piping plovers (McConnaughey *et al*. 1990), destroy nests (Hoopes *et al.* 1992) and kill chicks (Cairns & McLaren 1980).

Liley (1999) and others have observed that disturbance by dogs and people both invoke adult common ringed plovers with chicks to perform 'broken wing' distraction displays. However, unlike most people who quickly lost interest and walked on, Liley noted that dogs chase them, and the adult birds at his study site would lead such dogs out of their territories with this display, often far out onto adjacent tidal mud flats. Although not quantified, this behaviour is presumably energetically costly and may impact both on foraging activity of the adults and young (that crouch and hide in response to danger), and at least one chick was seen to be eaten by a dog.

In Australia, Dowling and Weston (1999) examined whether dog management on beaches increased reproductive success of hooded dotterel. Hatching success in areas of differing dog management i.e. no dogs from 09:00-17:00 h (although this was sometimes ignored by dog owners) versus where dogs were permitted at any time, were compared. They considered that there was no intrinsic difference in habitat quality which might otherwise confound the results. Hatching success was significantly higher where there was dog management (12.2% of clutches hatching) compared to where dogs were permitted, where none hatched. It is possible that some eggs were crushed or eaten by dogs (no direct evidence given), and also that by flushing incubating adults opportunistic predators benefited. Another comparison was made of the average number of chicks that fledged per clutch in areas designated as dog-free (but people allowed) with areas with dogs (dogs and people allowed at all times). There were a significantly higher proportion of chicks fledging in dog-free areas (averaging 0.65/clutch), compared to areas with dogs where no chicks fledged. At this locality, management implementation and better enforcement as the study progressed had a positive effect on hooded dotterel breeding success, with losses attributed to dogs being greatly reduced as a consequence.

No identified studies quantified the effect of dog disturbance on gamebird breeding success (see also '5.5 Lekking species'), but the opinions of those with knowledge of these species is that dogs cause problems. In a questionnaire survey of the effects of recreational disturbance of western capercaillie, Marshall (2005) found that nearly 75% of respondents (who had a working knowledge of this species e.g. land managers and gamekeepers) rated walking with a loose dog as causing the highest level of disturbance, regardless of time of year. Even when the scenario was that dogs were under control, overall opinion was similar, highlighting the perceived perception that dogs are a major cause of concern. Lek and brood rearing times were considered the most critical periods,

and loose dogs allowed to range away from tracks were deemed a disturbance threat throughout the year. Good quality habitat providing cover was thought to some extent, to mitigate disturbance effects.

Two studies (Picozzi 1971, Hudson 1982) looked at breeding success and density of red grouse *Lagopus lagopus scotticus* in relation to human disturbance and associated dogs. They found that there was no difference in performance of grouse populations on open access compared with no public access moorlands. But Hudson (1982, *in* Taylor 2005) in a simple non-replicated experiment showed that in the grouse breeding season, a dog off-lead was likely to disturb 7-times more red grouse compared to one on a lead; whether this affected breeding success was not investigated.

5.3.3 Disturbance at leks

Some lekking species may be especially vulnerable to human disturbance during the lekking period. The breeding success of black grouse and western capercaillie for example, is heavily dependent on the males being able to display effectively to females on traditional leks, this may be compromised by human presence in the vicinity of lekking grounds. A meta-analysis of mating success in lekking males (Fiske *et al*. 1998) highlights that behavioural traits such as male display activity and lek attendance are positively correlated with male mating success.

Although human disturbance is frequently cited as a factor contributing to population declines, evidence tends to be anecdotal. For example, in the Peak District of England, there was a sharp decline, with extirpation of several populations of black grouse between 1975 to1985. Increased human disturbance, as well as severe habitat loss and persecution, was considered a major contributory factor (Yalden 1986) but no evidence is given. Likewise, disturbance has been cited as a factor responsible for western capercallie declines in several European countries e.g. in Switzerland (Mollet *et al.* 2003) and Spain (Pollo *et al.* 2005).

Only one quantitative study was identified that attempted to determine the effect of human disturbance on foot on breeding success of a lekking species. This study (Baines & Richardson 2007) experimentally assessed the effects of human disturbance on back grouse in northern England. In the UK, black grouse are potentially at risk from increased human recreational disturbance owing to their threatened status and use of habitats to which a statutory right of human access through the CRoW Act has recently been granted. However, disturbance treatments were not undertaken in the vicinity of leks and the disturbance regimes tested (see Appendix 1) had no discernible impact upon breeding success or grouse populations.

Marshall (2005) undertook a capercaillie recreational disturbance study in Scotland using the ‘Delphi technique’ (a method to evaluate outcomes of actions in scenarios where absolute answers are not available). This involved collating opinions of those with a good knowledge of the species via questionnaires. Disturbance of lekking capercaillies was considered to have potentially major consequences, leading to failure of females to mate

and thus breeding opportunities being lost, possibly for the whole season; the brood rearing period was also considered critical. Loose dogs allowed to stray from tracks were considered a prime disturbance threat (see '5.4.Domestic dogs and disturbance'). In recent years, increased public interest in finding leks to view displays was considered an additional threat to the dwindling Scottish capercaillie population. In response, protection afforded to capercaillie was increased by listing it on Schedule 1 of the Wildlife and Countryside Act (UK), which makes it an offence to intentionally or recklessly disturb lekking grounds. Summers *et al*. (2004) also found that capercaillie in Scotland avoided woodland alongside trails (1 ha/46 m to 1 ha/82 m of track) that were used by people and their dogs, and suggest that the removal or closure of tracks might increase the extent of woodland available to capercaillie through reduction of disturbance.

Baydack and Hein (1987) found marked intersexual differences in the response to disturbance of sharp-tailed grouse *Tympanuchus phasianellus* at leks in Manitoba, Canada. Male grouse continued to display despite test disturbances (i.e. parked vehicles, exploders, scarecrows, taped voices, radio noise and unleashed dogs) in the lek vicinity. They were only displaced upon the approach of a person but even then generally remained within 400 m of the lek, returning quickly (usually within 5 min) upon cessation of disturbance. Females however, were never observed at leks during these disturbances. The authors therefore suggest that onset of breeding might be delayed and mating opportunities lost at heavily disturbed leks. Male sage grouse *Centrocercus urophasianus* (another North American species) were noted to be much more prone to disturbance. When flushed by human presence most did not return for 20-30 min, whilst some wary individuals did not reappear at the lek until the following day. Sage grouse are declining throughout their range and in several management plans, supervision of public access for viewing leks is recommended (e.g. Connelly *et al.* 2000). Joslin and Youmans (1999), based on field observations, advocate prohibiting recreational activities within 2.4 km (1.5 miles) of leks.

Kålås *et al.* (1995) undertook a study of great snipe *Gallinago media* on Dovrefjell, Norway. Flushing experiments were made at two leks in 1990, males being flushed during three periods from the end of May to the beginning of July. One observer flushed the male snipe at midnight (just before the females usually arrived) by walking from a hide across the lek and back again (about 15 sec duration), where upon all birds left the lekking ground. The time each male took to return was recorded. They did not become habituated to flushing (i.e. the average time spent hiding did not change significantly). Although this study focussed on mating probability in relation to disturbance and risk taking, Frid and Dill (2002) referring to this study, state, purely on conjecture, that an ecotourist disrupting a lek and remaining to take photos would force lek members to hide longer thus precluding matings, inferring that this is therefore a problem for the species. Such events might occur, but one of the authors of the Norwegian study considers human disturbance at great snipe leks not to be a problem in Scandinavia (Stein A.Saether pers.com. 2006). The 'International Action Plan for the Conservation of the Great Snipe' (Anon. 2004) states that recreational activities (e.g. tourism and fishing) may interfere with lekking birds and disturb breeding, and that human activities in breeding areas can facilitate the discovery of nests by predators, but no evidence is presented.

6. DISCUSSION

6.1 Evidence of impacts of human disturbance

This review has collated evidence from studies worldwide which have investigated the impact of human disturbance on foot (including associated pet dogs) on breeding ground-nesting and cliff-nesting birds, with most information coming from research conducted in Western Europe, North America, Australasia and South Africa. The results of the meta-analyses indicate that the bulk of the quantitative evidence relating to pre-fledging survival and chick weights suggest no effects of human disturbance, whilst the effects for fledging success are small and ambiguous. Evidence for hatching success is more indicative of a problem (but based on a small sample size). Most studies examined, both quantitative and qualitative/observational, point to human disturbance being detrimental to breeding success of a variety of ground-nesting species (including eider duck *Somateria mollissima*, brown pelican, adelie penguin, four gamebirds, 13 species of wader, three species of gulls, European nightjar, and five species of passerine). However, both the generally low quality of study designs and the anecdotal nature of many reports means that this evidence is highly susceptible to bias.

Human disturbance has been reported to have potentially detrimental impacts throughout the breeding cycle. There are some observations indicating that at the onset of breeding activity, displaying birds may be disrupted e.g. in the vicinity of leks, and territory establishment and nest placement may be influenced by the presence of people (with or without accompanying dogs). As with many studies looking at the effects of human access disturbance on ground-nesting birds, a difficulty of those looking at the associated problem of disturbance caused by dogs is that the measures of disturbance differ widely (Taylor *et al.* 2005). This therefore makes comparisons between studies tricky and drawing conclusions from and making practical use of them to draw up management plans, accordingly difficult. Despite this, available evidence (albeit frequently based on *ad hoc* observations and therefore probably inadequate to draw any firm conclusions) suggests that pet dogs impact on breeding ground-nesting birds, either directly through predation of eggs, young and very occasionally adult birds, or perhaps more seriously displacement of incubating or brooding adults leading to predation opportunities for opportunistic predators.

6.2 Reasons for variations in impact

Possible reasons for variation of impact of human access disturbance on breeding success of the ground nesting bird species for which studies have been undertaken are many. Taking into account all relevant studies (regardless of whether subject to meta-analysis or not) indicates that the scale of impact is highly variable between species, occasionally within species at differing sites, and dependant upon many factors, but primarily:

i) the period in the breeding cycle when disturbance occurs (i.e. from initial adult territory establishment and settlement, through the incubation and chick-rearing phases, to fledging of young); there tended to be greater vulnerability

to disturbance during the incubation period. Eggs of non-colonial beach-nesting species were especially vulnerable to trampling in areas of high human visitation. When adults were displaced by approaching people or dogs, eggs were sometimes prone to predation and perhaps also thermal stress (although there was no absolute evidence for the latter, this is a reasonable assumption). In some cases were colonial birds were involved, e.g. brown pelican and gull colonies, the mayhem that ensued following disturbances led to the birds themselves causing losses either through accidental trampling of eggs or young, or mortality of young straying from the nest territory by neighbouring pairs.

ii) the type and intensity of disturbance; this study looked specifically at human access on foot and associated activities (i.e. walking, dog-walking, bird-watching, cross-country running, picnicking, angling, climbing, mountain - biking, horseriding), versus no access or access at a lesser intensity. However, given the nature of the issue, disturbance levels are inherently difficult to qualify and quantify.

iii) the presence of opportunistic predators that can take advantage when attending adult birds are driven from eggs and/or young due to disturbance; in several studies, especially of waders (shorebirds) but also other taxa, it appeared that predation opportunities were enhanced by disturbance (both by people and/or dogs). Upon approach, adult birds were displaced, and predators (mainly corvids and gulls) in the vicinity were able to locate eggs by observing the movements of the fleeing adults.

iv) degree of habituation to people; in breeding areas regularly visited e.g. by ornithologists, researchers or ecotourists, some birds including several penguin and tern species, appeared habituated to a greater or lesser degree to regular (controlled) human visitation. In comparison, those same species exposed to less regular disturbance exhibited higher responses upon approaches manifested by reduced breeding success and/or behaviour indicative of alarm or threat, e.g. distraction displays, fleeing the nest or reduced provisioning of the young.

6.3 Methodological limitations

There are several methodological limitations that need to be considered including: limitations of the quality of original research, extraction of data and publication bias.

The original research included in the review is of variable quality, with some of the currently available studies being of inadequate duration and data are sometimes difficult to interpret. Levels of impact on breeding success are difficult to compare in many cases as methods are highly variable between studies. The small sample sizes and large number

of ecological and methodological study characteristics severely restricted the potential to explore variation across species, sites and studies.

Meta-analyses are based on small sample sizes and there is significant heterogeneity – thus care needs to be taken when interpreting pooled effects. Studies are difficult to compare because the intensity of disturbance is variable and outcomes are measured in different ways. Sample sizes are too small for individual studies to be significant given the magnitude of effect suggesting that bigger sample sizes are needed in future disturbance work. Sample sizes are too small to assess impact of publication bias, except for fledgling success, so the potential for bias is unknown.

Data extraction introduces bias where variance is imputed, particularly if the variance is calculated from summary statistics. This method is defensible provided the bias does not overweight the study, but the combination of large numbers of studies with imputed variances remains problematic for both pre-fledgling survival and fledgling success. Sample sizes were too small to explore this using sensitivity analysis.

Although steps were taken to minimize publication bias by searching grey literature, it is possible that some studies were not identified despite efforts to do so. In a very few cases where existence of a report or research project was known about but could not be located, or in order to try and obtain data, authors were contacted by e-mail. Reponses for requests for data met with low success.

7. REVIEWERS CONCLUSIONS

7.1 Implications for conservation

The evidence base derived from experimental studies on the impact of disturbance on the breeding success of ground- and cliff-nesting birds is weak. This is primarily due to the limited amount of comparable quantitative data between studies amenable to meta-analysis. Thus, based solely on the outcomes of the quantitative syntheses of higher quality studies, the significance of disturbance is unclear. Qualitative and observational/anecdotal evidence on the impact of human disturbance on foot (and associated activities which were addressed in the available literature i.e. dogs, picnicking, angling, climbing and ecotourism) upon ground-nesting and cliff-nesting birds suggests that in the great majority of reported cases, disturbance has a negative effect on breeding success. But level of bias in reporting is unknown. Evidence for habituation to disturbance is mixed; it has been shown for several bird species that they will become habituated to human presence (e.g. Lord et *al*. 2001, Ikuta & Blumstein 2003) but with many species exhibiting increased sensitivity to higher disturbance levels. Of those very few studies looking at affects of disturbance at the population level (e.g. Liley 1999, Mallord 2005), human disturbance constrained population sizes. Such studies indicate that breeding density of some species (e.g. of common ringed plover *Charadrius hiaticula*, Eurasian golden plover *Pluvialis apricaria*, dunlin *Calidris alpina*, European nightjar *Caprimulgus europaeus* and woodlark *Lullula arborea*) is substantially reduced

by the occurrence of recreational disturbances. Such reduced breeding density, or even abandonment of otherwise suitable habitat, may be a major, or the main consequence of human disturbance.

Given the variable outcomes of the results of studies, it is apparent that for most species in most situations, management options to regulate human visitation in the vicinity of nesting areas should be guided by the sensitivity of the species affected, the form of disturbance, and predicted disturbance intensity. Given this, however, some precautionary interventions, e.g. fencing off of nesting areas on beaches during the breeding season, restricting unregulated access to lekking grounds, ensuring walkers adhere to designated paths, and regulations to ensure dogs are leashed in sensitive areas, are broadly applicable, and pertinent for encouraging territory establishment and nesting, or maintaining or enhancing breeding success.

7.2 Implications for research

Only six studies (Flemming *et al* 1998, Yalden & Pearce-Higgins 1997, Liley 1999, Finney *et al.* 2005, Mallord 2005 and Taylor 2007) vigorously address the impact of human disturbance on ground-nesting birds at the population level**.** Many other studies have looked at impacts of disturbance on breeding success and displacement to varying degrees. Some are peripheral investigations undertaken in conjunction with other research, often conducted only over part of a breeding season, or one or two breeding seasons. More longer-term studies could therefore be usefully undertaken, both looking at the impact of human disturbance on breeding success (reduced breeding densities or site abandonment) and exploring viable management options to mitigate impacts.

There are few studies that look at the effect of human disturbance on cliff-nesting birds. A number looked at location of nest sites in relation to surrogates for human disturbance, such as proximity of human settlements and roads, but samples sizes are often very small and results ambiguous as confounded by other factors. Where colonial nesting species are concerned, future studies should strive to include true replication of treatments whenever possible.

Habituation to human disturbance is another area where further investigation is warranted. Other than a few specific studies of several species of penguin, conclusions drawn are often somewhat anecdotal due to confounding environmental factors, or observations (with no structured experimental design) being made during the course of other studies. Studies by Cobley & Shears (1999; gentoo penguins) and Yorio and Boersma (1992; Magellanic penguins), suggest no detrimental effect of disturbance (based on behavioural observations and reproductive parameters) and that these penguins appear habituated to human visitation in colonies regularly visited by tourists. However, Walker *at al*. (2006, 2008) and Ellenberg *et al*. (2009) show that some penguin species or individuals within a colony may suffer from physiological stress due to human visitation, that could have important effects that are difficult to detect in the typically short-term studies conducted. McClung *et al.* (2004) showed that yellow-eyed penguins never

became particularly habituated to human visitation and that chicks had a significantly lower weight in a disturbed compared to undisturbed site; this is one of the very few long term studies (using a 20 year data set) attempting to assess whether fledging weight is a predictor of juvenile survival; survival probability was positively correlated with weight at fledging. More and longer-term studies addressing these issues would be pertinent.

Domestic dogs clearly pose a different form of threat to ground-nesting birds than people, and although dogs do unequivocally cause problems for some ground-nesting birds, to date most evidence for this comes from *ad hoc* observations or is anecdotal. Very rarely has an attempt been made to isolate the effect of dogs from the people that normally accompany them. Thus studies that quantify the impact of dog-induced disturbance on breeding success could usefully be undertaken.

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10. APPENDICES

Appendix 1. Characteristics of disturbance studies with potential data suitable for meta-analysis (* indicates used in meta-analysis).

Species	Reference	Ecological; habitat & country/region	Method	Data	Outcome
Anatidae					
Common eider *Somateria mollissima*	Bolduc & Guillemette (2003)	Nesting success in vicinity of nesting large gulls *Larus* spp. Habitat: rocky shore (Canada)	Experimental high (once every 3 days) vs. low (once every 15 days) frequency human disturbance. Each visit involved walking through an eider colony and deliberately flushing females off nests; not deemed typical disturbance from a walker (rather 'researcher disturbance'), therefore excluded from the analysis.	1 data point: probability of eggs hatching under high (0.32) and low frequency (0.43) early-season disturbances.	Upon flushing incubating female from nest opportunities presented for large gulls to predate eggs.
Spheniscidae					
Gentoo penguin *Pygoscelis papua*	*Holmes *et al.* (2006)	Incubation period to chicks joining crèche; (6-8 weeks in 2002). Habitat: beach (Australian Antarctic)	49 breeding colonies, 2 counts to ascertain: i) no. of breeding pairs during incubation/guard phase; ii) number of chicks raised to crèche age. Number of chicks reared compared between areas 'on-station' (high human activity, inc. some vehicular disturbance) and 'off-station' (low human disturbance).	1 data point: mean productivity of chicks reared to crèche age. 1.43 chicks/pair 'on station' ; 0.9 chicks/pair 'off station'	No. of chicks raised/pair higher in colonies with greater human disturbance.
	*Cobley & Shears (1999)	Chick weight at 20 days; 1996-97 austral summer. Habitat:	Tourists excluded from 4 colonies (control), but allowed to walk around 6 colonies under	1 data point: weight of chicks at 20 days in a disturbed (n = 10) and	No difference in average chick weight >< disturbed and

		low-lying islet (Antarctica)	supervision (disturbance treatment).	control colony (n = 12)	control colonies.
Adelie penguin *Pygoscelis adeliae*	*Giese (1996)	Chick survival/nest up to 2 weeks of age, 10 Nov 1993 to 18 Jan 1994. Habitat: rocky coast (Antarctica)	Six colonies (3 larger, mean 70 nests; 3 smaller, mean 44 nests) exposed to disturbance treatments (nest checks and recreational visits) vs. no disturbance (control). Breeding success examined in terms chick survival to 2 weeks old (estimated to within 48 h). This permits only a conservative estimate of overall nest failure, but chicks were unmarked thus difficult to determine fate at later stages.	2 data points: 1) No. of nests with at least 1 chick raised to 2 weeks old in smaller colonies; 2) no. of nests with at least 1 chick raised to 2 weeks old in larger colonies).	Smaller colony size: 5/37 (14%) nests (disturbed) and 31/37 (84%) nests (control) with at least 1 chick. Larger colony size: 62/75 (83%) nests (disturbed) and 58/63 (92%) nests (control) with at least 1 chick.
Yellow-eyed penguin *Megadyptes antipodes*	*McClung *et al.* (2004)	Fledging weight and fledglings/pair; 2001-2002 breeding season. Habitat: beach (New Zealand)	Fledging weight estimated by weighing chicks within approx. 4 weeks before first entering the sea at five beaches: one beach categorised 'high level of human disturbance'; three 'low to moderate disturbance'; and one 'least disturbed'. Number of young successfully fledged/pair in a more disturbed (n=19 breeding pairs) vs. less disturbed (n=14 pairs) area	2 data points: Mean fledgling weight of chicks related to the degree of human disturbance, either high (1 beach) or least disturbed (1 beach). Low-moderate levels of disturbance excluded in this analysis). Fledging success	High disturbance beach: mean chick weight 5.32 kg (SD 0.602). Least disturbed beach: mean chick weight 6.08 kg (SD 0.794). High disturbance 0.95/pair; less disturbed 0.79/pair
Magellanic penguin *Spheniscus magellanicus*	*Yorio & Boersma (1992)	Fledgling weight; no. of chicks/active nest Habitat: beach (Argentina)	Fledging weight estimated by weighing chicks in a tourist (more disturbed) vs. non-tourist (less disturbed) area.	2 data points: mean fledgling weight of chicks and chicks fledged/active nest, related to the degree of human disturbance.	Mean fledging weight similar in tourist area 2.40 kg (SD 0.35; n=50 nests) vs. non-tourist area 2.33 kg (SD 0.33;

			Breeding success (chicks fledged/active nest) in a tourist (more disturbed) vs. non-tourist (less disturbed) area.		n=50). Mean number of chicks/pair similar in tourist area 1.06 (n=36 nests) vs. non-tourist area 1.04 (n=54).
Pelicanidae					
Brown pelican *Pelicanus occidentalis*	*Anderson & Keith (1980)	Young fledged/nest built (data from 3 breeding seasons, 1971, 1972, 1974). Habitat: beach (USA)	Young fledged compared >< disturbed area (nests disturbed by human visitors at egg/small young stage i.e. humans had approached nesting birds, but not always walking amongst active nests) and undisturbed nests.	1 data point: Mean productivity (young fledged/pair) of disturbed vs. undisturbed nests.	Productivity much lower, 0.26 fledglings/pair (n=2,663 nests) in disturbed area vs. 1.33 (n=3,328) in undisturbed area.
Phasianidae					
Black grouse *Tetrao tetrix*	*Baines & Richardson (2007)	Hatching success. Habitat: moorland (UK)	Three experimental disturbance treatments: no disturbance (low), fortnightly disturbance (moderate) or twice weekly disturbance (highest) by walker.	1 data point: % hatching success of no disturbance vs. highest disturbance.	Hatching success similar between no disturbance 48% hatch success (n=22 nests) vs. highest disturbance 46% hatch success (n=33).
Charadriidae					
Eurasian golden plover *Pluvialis apricaria*	*Finney *et al.* (2005)	Proximity of nesting pairs to a major footpath (Pennine Way) over 12 breeding seasons (1986-1998). Habitat: moorland (UK)	Surveys during nesting period recording fledging success of broods (to the nearest 100 m grid square) from 100 m to 1,200 m.	1 data point: brood survival to fledging in relation to nearest (within 100m) distance of territory, and furthest (1,100-1,200m) from footpath. Raw residuals from logistic regression control for significant effects of habitat type and date, plotted at 100 m intervals.	Brood survival to fledging higher at closer distance to path (20%) vs. at furthest distance from path (10%) surveyed

Haematopodidae					
Eurasian oystercatcher *Haematopus ostralegus*	Verhulst *et al.* (2001)	Proportion of time eggs incubated over 3 days of observation in 1999. Habitat: saltmarsh (Netherlands)	Three days of observation of 4 pairs, each day observing during 1 low tide period. First and third day used as control, second day foraging adults actively pursued and pushed off territory during 1 low tide cycle.	1 data point: proportion of time eggs incubated when adults not disturbed (foraging in feeding territory), and when pursued and pushed out of feeding territory. (Not used in analysis as lacking comparable data).	Disturbance significantly reduced the proportion of time that eggs were incubated.
Common sandpiper *Actitis hypoleucos*	*Yalden (1992)	No. of hatching territories and fledging territories around shoreline over 2 breeding seasons, 1989 and 1990. Habitat: upland reservoir (UK)	Alternate Saturdays and Sundays devoted to either sandpiper surveys or angler counts (i.e. measure of disturbance) around reservoir shoreline.	2 data points: no. of hatching territories and no. of fledging territories. Comparison of breeding success for territories between 'quiet' (<6 people/km of shoreline/survey visit) and 'busy' >6 people/km/ visit).	In busy territories (n=17) 71% of nests hatched; in quiet territories (n=40) 58% hatched. In busy territories (n=23) 65% fledged young; in quiet territories 83% fledged young.
Common ringed plover *Charadrius hiaticula*	*Liley (1999)	Breeding parameters including territory establishment, nest and chick survival, and fledging success in relation to human disturbance; over three years, 1996-1998. Habitat: beach (UK)	Various studies undertaken on beaches/beach front occupied by breeding plovers	4 data points: 1) survival through incubation; daily nest survival rate at highest human disturbance level vs. lowest. 2) mean % of eggs fledging in areas with human access (eggs prone to trampling) vs. no access. 3) Effects of disturbance intensity (people counts within 120m beach sections)	1) daily nest survival rate 68% (n=16 nests) at highest disturbance vs. 94% (n=139) lowest level. 2) 4.55% of eggs fledged in areas with human access (n=36 nests) vs. no access 12.64% (n=17). 3) Nest density declined with increasing numbers

				on nest density. (Excluded from analysis as too related to other variables and insufficient comparable data from other studies). 4) Time chick foraged/30min observation when people within 100m of brood cf. when no people within 100m (data point excluded due to lack of comparable data).	of people. 4) Chick foraging time reduced in areas with more people but this had no effect on growth or survival to fledging.
	*Pienkowski 1984	Hatching success Habitat: beach (UK)	Hatching success of nests recorded in areas categorised according to three levels of human visitation: high (100+ human visitors/day); moderate (up to 50 visitors/day); low (c.5 visitors/day).	1 data point: hatching success in high disturbance (100+ visitors/day) vs. low disturbance (c.5 visitors/day) areas.	Nest survival to hatching averaged 50.5% (n=50 nests) in low disturbance area (27% moderate disturbance) and 1.7% (n=55) in high disturbance area.
Piping plover *Charadrius melodus*	*Flemming *et al.* (1988)	Study over 4 breeding seasons (1979-83). Habitat: beach (Canada)	Levels of disturbance were quantified over five years (1979-1983) by recording positions of people, their footprints and vehicle tracks. Surveys (4 breeding seasons) recorded number of chicks surviving/nest attempt to 10 days old and to 17 days old (fledging) on beaches subject to high and low disturbance.	2 data points: Chicks surviving to 10 days old /nest attempt and chicks surviving to fledging/pair, in areas of high vs. low disturbance (means over 4 breeding seasons).	Chicks survival to 10 days old was 1.2 chicks/pair (n=18 nests) in high vs. 1.8 chicks/pair (n=24) in low disturbance areas. Number of chicks fledging was 0.5/pair (n=16) in high vs.

					1.8/pair (n=21) in low disturbance areas.
Snowy plover *Charadrius nivosus*	*Ruhlen *et al.* (2003)	Chick mortality at high compared to low disturbance days. Habitat: beach (USA)	Surveys recorded proportion of chicks lost at weekends/holidays (higher disturbance) cf. chicks lost on weekdays (lower disturbance)	1 data point: cumulative mean percent chick survival on high disturbance vs. low disturbance, days	Of the initial 83 nests, a higher proportion of chicks survived on low disturbance days (65%) vs. high disturbance days (35%).
Hooded dotterel *Thinornis rubricollis*	*Dowling & Weston (1999)	Monitoring of plover breeding parameters over 7 breeding seasons (1991-1998). Habitat: beach (Australia)	Surveys undertaken to determine: proportion of nests that hatched and causes of clutch loss on beach vs. dunes; mean number of fledglings/clutch at nests on beach with 'least managed conditions' (i.e. walkers and their dogs on a lead, allowed at all times vs. 'most intensive management regimes' (i.e. no dogs; Plover Watch; restricted access); proportion of clutches hatching on beaches where dogs and people allowed (more disturbed) cf. where people allowed but not dogs (less disturbed).	3 data points: 1) hatching success of nests on beach (more disturbed) vs. on dunes (less disturbed). 2) fledging success of beach nests under least managed vs. most intensive management regimes. 3) proportion of clutches hatching on beaches where dogs and people allowed cf. where people allowed but not dogs.	1) Of 41 beach nests 10 (24.4%) hatched (21; 51.2%, were trampled). Of 56 dune nests 23 (41.1%) hatched (12; 21.4%, were trampled). 2) Of 49 nests on 'least managed' beaches, no chicks fledged; of 40 nests within sections under most intensively managed, 0.53 fledged/nest. 3) 0% of clutches (n=49) where dogs and people allowed vs. 40% (n=5) where people allowed but not dogs hatched.

	Weston & Elgar (2005)	Disturbance effects of brood-rearing on chicks, 1995-1998. Habitat: beach (Australia)	Each brood observed on days of relatively high disturbance (weekend or public holiday) and relatively low disturbance (often a non-public-holiday weekday). Number of human/brood encounters and time chicks spent hiding recorded.	1 data point: time chicks hiding on relatively disturbed vs. relatively undisturbed days. (Excluded from analysis as comparable data lacking).	Chicks unable to solicit brooding when hiding. Number of mins spent hiding/h significantly higher on relatively disturbed (30.1 ± 15.6 min) compared to relatively undisturbed (22.5 ± 14.6 min), days.
Laridae					
Least tern *Sterna antillarum*	*Burger *et al.* (1995)	Effects of disturbance on fledging success at tern colonies (1983-1990). Habitat: beach (USA)	Surveys undertaken to assess success in relation to human disturbance categorised as: i) primarily ecotourists (birdwatchers); ii) primarily other types of human disturbances (sun-bathers, joggers, fishermen – considered most pertinent to the present review); iii) few ecotourists and few disturbances	2 data points: 1) Percentage of pairs raising >0.5 young/pair in more frequently disturbed colonies (ii) vs. colonies with few disturbances (iii). 2) Percentage of pairs raising 0.1 - 0.5 young/pair	1) 29% of pairs (n=12 colonies) raised >0.5 young/pair in more frequently disturbed colonies vs. 73% (n=13) with few disturbances. 2) 32% of pairs (n=13 colonies) raised 0.1-0.5 young/pair in more frequently disturbed colonies vs. 27% (n=5) with few disturbances.
Bridled tern *Onychoprion anaethetus*	*Gyuris (2004)	Effect of low-moderate disturbance on breeding success at colonies on Great Barrier Reef islands (1995-1998). Habitat: beach (Australia)	Two levels of disturbance schedules implemented over 2-3 breeding seasons: i) 5 sites monitored every fourth day to record status of eggs/chicks (2-3 people walked through colony, ringed and weighed chicks; disturbance time kept to a minimum); ii) 3 of the sites	2 data points: 1) Mean chick weight at 12-13 days at 'monitored only sites' vs. 'disturbance sites'. 2) Mean chick weight at 20 days (fledging) at 'monitored only sites';	1) At monitored only sites mean chick weight at 12-13 days (69.3g) significantly less than disturbance sites (77.4g). 2) At monitored only sites mean chick

			('disturbance sites') also disturbed experimentally to simulate low-moderate level visitation (visitor intrusion for 3 h/week) experienced on many islands.	vs. 'disturbance sites'.	weight at 21-22 days (103.5g) but not significantly less than disturbance sites (106.8g)
Black-legged kittiwake *Rissa tridactyla*	*Beale & Monaghan (2004)	Breeding success during 2002 breeding season. Habitat: sea cliffs (UK)	106 nests selected. Fledging success recorded. Number of people along paths in vicinity recorded. Disturbance parameters (previously identified in as potentially significant) affecting nest success modelled.	1 data point: effect of increased vs. decreased visitor numbers on fledging success.	40% increase in visitor numbers, c.2% fledging success. 50% decrease in visitor numbers c.96% fledging success.
Heermann's gull *Larus heermanii*	*Anderson & Keith (1980)	Number of young/100 adults at 2 colonies in 1974 breeding season Habitat: beach (USA)	3 human disturbance intensities (no known disturbance, moderate and heavy). Number of young then related to degree of disturbance.	1 data point: Number of young fledged/100 adults at heavy vs. no known disturbance colonies.	4.5 young/100 adults (n=1,281 adults) at heavy vs. 17.7/100 adults (n=1,421 adults) at no known disturbance colonies.
American herring gull *Larus smithsonianus*	*Hunt (1972)	Eggs hatching and young fledged/nest at colonies on islands during 1968-1970 breeding seasons. Habitat: coastal islets (USA)	Percentage of chicks hatching and young fledged/nest recorded at colonies on islands subject to more vs. less frequent visitor disturbance (mainly picnickers); measured subjectively on basis of 'number of old fireplaces, beer cans and picnic groups' encountered during visits	2 data points: 1) Percentage of chicks hatched/eggs laid on more vs. less disturbed island. 2) Number of fledglings produced/nest on more vs. less disturbed island.	1) 22% of eggs hatched on more disturbed (n=375 nests) vs. 49.5% on less disturbed (n= 483) island. 2) 0.288 fledglings/nest on more disturbed vs. 0.606/nest on less disturbed island.
Alcidae					
Common guillemot *Uria aalge*	*Beale & Monaghan (2004)	Breeding success during 2002 breeding season. Habitat: sea cliffs (UK)	241 nests selected. Fledging success recorded. Number of people along paths in vicinity recorded. Effects of parameters affecting nest success modelled.	1 data point: effect of increased vs. decreased visitor numbers on fledging success.	40% increase in visitor numbers, c.36% fledging success.

					50% decrease in visitor numbers c.87% fledging success.
Peregrine falcon *Falco peregrinus*	*Brambilla *et al*. (2004)	Fledging success of cliff-nesting peregrines in 2002 and 2003 breeding seasons. Habitat: inland cliffs (Italy & Switzerland)	Proportion of pairs (=nests) producing fledged young on cliffs with climbers only (n=2 pairs) cf. those on cliffs with climbers and ravens *Corvus corax* (n=5), and no climbers or ravens (n=14).	1 data point: Nesting success (young reared to fledging) at cliff sites with climber disturbance only (i.e. no raven present) vs. no human disturbance.	50% of nests (n=2) producing fledglings on cliffs with climbers; 79% of nests (n=14) producing fledglings on cliffs with no climber disturbance.
Western marsh harrier *Circus aeruginosus*	*Fernández & Azkona (1993)	Effects of low levels of human disturbance on parental care and nestling nutritional status, 1991 breeding season. Habitat: marsh (Spain)	Changes in reproductive activities, nutritional condition and fledging success monitored.	1 data point: Fledging success of pairs subject to low levels of human disturbance vs. no human disturbance.	In nests (n=6) subject to low levels of disturbance 64% (25 eggs laid, 16 chicks) fledged; Similarly in nests (n=5) subject to no disturbance 67% (24 eggs laid, 16 chicks) fledged.
Passeriformes					
Woodlark *Lullula arborea*	Mallord (2005)	Density of breeding pairs/ha of suitable habitat in 2002 and 2003. Habitat: heathland (UK)	Density of breeding pairs/ha of suitable habitat recorded at heathland sites and related to observed levels of human visitation (people/survey/ha).	1 data point: Density of breeding pairs/ha at sites (n=3) with low disturbance (<0.01people/survey/ha) cf. density at sites (n=5) with highest disturbance (>0.1 people/survey/ha). Comparable data lacking from other studies therefore excluded from analysis.	At low disturbance the density of woodlark pairs was around 0.6 pairs/ha of suitable habitat, at the highest disturbance level densities were 0.1-0.2 pairs/ha.

Western meadowlark *Sturnella neglecta*; Vesper sparrow *Pooecetes gramineus*; Grasshopper sparrow *Ammodramus savannarum*	Miller *et al.* (1998)	Number and distance of nests from trails over 5 weeks in 1994 and 7 weeks in 1995. Habitat: grassland (USA)	Nests were located from the edge of trails out to 200 m, ensuring equal search effort at all distances. Probability that a nest will occur at a given distance from trails and control transects. Due to small sample sizes of nests for some species, analyses of individual species not possible.	2 data points: 1) predicted probability that a nest will occur at 0 m vs. at 200m 2) Predicted probability that a nest will survive in grassland one day at increasing distance from trails. Comparable data lacking from other studies therefore excluded from analysis.	1) Western meadowlark and grasshopper sparrow were less likely to nest near trails: 0.28 probability of a nest at 0m; 0.5 probability of nest at 200m. 2) Probability that a nest (all 3 species) would survive one day (n = 163 nests; 1,954 nest days) related to distance from trails; the further the distance from a trail, the higher the probability of survival.

Appendix 2. Summaries of studies of human access disturbance on breeding ground-nesting and cliff-nesting birds.

Species accounts are arranged within four habitat categories: i) beaches, rocky shores and marine islands; ii) cliffs; iii) heaths and lowland grassland; and iv) moorland, tundra and mountain.

BEACHES, ROCKY SHORES and MARINE ISLANDS

Gentoo penguin *Pygoscelis papua*

Holmes *et al*. (2006) investigated the behaviour and breeding success of gentoo penguins in areas of high and low human activity on sub-Antarctic Macquarie Island (Australia). The area of high human activity encompassed the Australian Antarctic Program station limits, within which penguins were exposed to general pedestrian and vehicle activity as required to run the station, and also controlled human approaches. Low activity areas were beyond the station limits where human visitation, except for approach experiments, was kept to a minimum during the breeding season (from egg-laying onwards). Approach experiments were conducted on penguins nesting at the edge of colonies as these were exposed to the greatest potential pedestrian disturbance, and this allowed for the influence of nest location to be standardized. The approach procedure comprised a before, during and after design to allow repeated measures of behavioural response as a person walked to within 5 m (the closest approach) of the penguins. In low disturbance colonies, gentoos displayed significantly higher levels of vigilance and threat display behaviour when approached. In contrast, those within the station limits (exposed to daily high human activity) showed little noticeable response to approaches, other than some evidence of increased vigilance and decreased resting, but not much different to pre-approach levels, suggesting that to a greater or lesser degree, these birds were habituated to this form and level of disturbance.

Breeding success was estimated by taking two counts at 49 of the 50 gentoo colonies on the island. The first count (during the incubation/guard phase) ascertained the number of breeding pairs. The second took place during crèche (when older chicks group together) to determine the number of chicks raised to crèche-age (about 6-8 weeks old). Average on-station breeding success was greater than off-station, however variation over-lapped with off-station colonies, and those beyond the station limits on part of the island had the highest density of colonies and highest breeding success. Factors other than human disturbance, such a habitat quality and presence of southern elephant seal *Mirounga leonina* harems (which disrupted breeding activity) were found to be important and influenced breeding success.

Cobley and Shears (1999) looked at the effect of visitor disturbance on gentoos over one breeding season at the popular ecotourist site of Goudier Island on the Antarctic Peninsula. Breeding performance was compared between colonies visited by tourists (35-55 people every 1-2 days) with nearby undisturbed colonies. There was no difference between the disturbed and undisturbed colonies in the proportion of birds that laid, in hatching success or proportion of single chick broods. There was also no difference in chick weight or survival up to 20 days of age, and survival to crèche age was high and similar between the two groups. Gentoos only became established as a breeding species on Goudier Island in

1985, since when the penguin population has grown rapidly. Human disturbance from regulated tourist visits appears not to be constraining population growth.

Adelie penguin *Pygoscelis adeliae*
Giese (1996) compared adelie penguin breeding success at colonies subject to different types and intensity of human activity within one breeding season in the Vestfold Hills, Antarctica. Three larger (about 70 nests each) and three smaller (about 44 nests each) colonies were exposed to one of three treatments (a treatment replicated at one colony of each size): nest checking (nests visited every second day for about 15 min); recreational visits (two to four, 10-min visits every day by two people walking slowly around the colony periphery 5 m from its edge, kneeling and taking photographs, thus mimicking tourist visitor intensity and activities); and no disturbance.

Hatching success and chick survival was highest in the two undisturbed colonies. In the smaller colonies exposed to disturbance treatments, hatching success and survival were significantly reduced: hatching success was 35% lower at the colony exposed to nest checking and 47% lower for recreational visits compared with the undisturbed colonies; chick survival was 72% and 80% less respectively. The two disturbance treatments also reduced hatching and chick survival at the larger colonies but not significantly so. South polar skua *Catharacta maccormicki* predating on eggs exposed during human disturbances at the smaller colonies is given as the most likely cause of egg loss, although no data is presented to support this.

Yellow-eyed penguin *Megadyptes antipodes*
McClung *et al.* (2004) explored the relationship between human disturbance and yellow-eyed penguin fledging weight and chick survival at colonies on the Otago Peninsula, South Island, New Zealand. Five breeding areas with different levels of visitor frequency were compared. In 2002 at one site with high tourist numbers, fledging weights were significantly lower than chicks in an area with no tourists. Whether fledging weight is a predictor of juvenile survival was investigated using long-term (1981-2000) data of re-sightings of ringed (banded) birds. This indicates that survival probability was positively correlated with weight at fledging. Fledging weight is influenced by many factors but results suggest that higher tourist visitation levels may have a detrimental effect on chick fledging weight and hence longer-term survival. Ellenberg *et al*. (2009), investigated habituation potential of yellow-eyed penguins in southern New Zealand. Individual birds differed significantly in both their initial stress response and habituation potential upon human approach (some habituated to short and consistent approaches, others did not). The authors conclude that this species appears unsuitable for unregulated tourist visits at nest sites.

African (Jackass) penguin *Spheniscus demersus*
Hockey and Hallinan (1981) assessed the effect of human disturbance on breeding African penguins at Jutten Island, Saldanha Bay, South Africa. Two types of disturbance were assessed: a person walking through a low-density colony (nests approx. 4 m apart) and approach on foot to a high density colony (nests approx. 1 m apart). Three low-density colonies each had a different level of human passage along a transect line: walked daily

(over seven days), walked every 2 hours (between 08:30-16:30 h on two consecutive days); and walked once every hour (between 09:00-17:00 h on two consecutive days). Two types of approach were made to high density colonies: two colonies (one coastal, one inland) were approached gradually to 10 m of the colony periphery (five stages, 10 min at each, recording bird behaviour); three colonies were approached directly (walking to 30, 20 or 10 m from the colony periphery). Adult penguins reacted most strongly to a direct approach, whereas chicks reacted most to a gradual approach. At coastal colonies, approaches led to a high exodus of birds with many leaving the colony (presumably to the sanctuary of the nearby sea where they felt safer) whilst no exodus of birds at inland colonies occurred, perhaps (although not stated) as they had no safe refuge to flee too.

Walking through colonies led to egg loss due to predation by kelp gulls *Larus dominicanus*, as incubating penguins sometimes temporarily abandoned their eggs at the approach of a person. Nest-prospecting penguins were scared away and were absent altogether after the fourth day of disturbance. These disturbance experiments were only conducted over 2-7 days, and the authors suggest that if such disturbance was continuous throughout the duration of the breeding season it could detrimentally affect reproductive success.

Magellanic penguin *Spheniscus magellanicus*

Yorio and Boersma (1992) looked at the effects of human disturbance on magellanic penguin behaviour and breeding success at Punto Tombo on the Patagonian coast of Argentina. Responses of penguins were investigated in this large (225,000 pairs) colony in four areas exposed to different forms of disturbance: a tourist area where visitors can walk amongst nests; within 15 m of a 1 km-long access road; a restricted area with no access except rare visits by rangers/researchers; and a scientific study area where nest checks are undertaken. Penguins in tourist areas were more tolerant of human approaches (allowing a significantly closer approach before eliciting threat and defence displays) than those in areas seldom visited. During incubation, to assess whether adults temporarily abandoned their eggs, controlled approaches were undertaken in two different habitats within the colony. A total of 286 'burrow' nests and 82 'bush' nests were approached along transect lines; no penguin abandoned its eggs. Breeding success (number of young fledged/active nest) and fledgling weights were similar in all four areas.

Walker *et al*. (2005) examined behavioural and physiological differences in chicks living in either tourist-visited or undisturbed areas of the Punta Tombo breeding colony. Newly hatched chicks in visited areas had higher corticosterone stress responses than newly hatched chicks in undisturbed areas (baseline levels were similar). By 40-50 days old and around fledging time, tourist-visited chicks did not move away when approached, whereas undisturbed chicks fled (when approached to no closer than 9 m). Although it is unknown whether chicks raised in visited areas suffer negative consequences due to an elevated stress response at hatching, they exhibit behavioural habituation to human approach by fledging age. A subsequent study (Walker, Boersma & Wingfield 2006) showed that habituation by adult magellanic penguins to human visitation is rapid. Walker *et al*. (2008) reviewed studies examining how endocrine stress physiology of magellanic penguins is modified by tourist visitation. In a colony showing few outward negative behavioural or other population-level effects due to human disturbances, some

potentially significant detrimental physiological modifications were apparent. The long-term consequences are unknown but raise concerns that there may be negative impacts due to visiting tourists.

Brown pelican *Pelicanus occidentalis*

Anderson and Keith (1980) looked at the effect of human recreation on beach-nesting brown pelicans in Baja California, Mexico. Breeding productivity in disturbed sub-colonies (humans in full view and closely approaching nesting birds) was compared with that of nearby undisturbed 'control' areas. Even only one disturbance event (whether caused by casual visitors or researchers) early in the nesting season had a severe effect; over three years average productivity (fledged young) was 80% less in disturbed areas. Detrimental disturbance effects manifested as loss of eggs and young following short- or long-tem abandonment by adults, and subsequent predation by e.g. western gull *Larus occidentalis* and commom raven *Corvus corax*. Gulls attacked even large chicks (up to 4-weeks old) in the absence of their parents, forcing them to regurgitate food or causing injuries resulting in later death. Some losses may have been attributable to hyper- or hypothermia, and trampling by adults and larger young. In addition, some larger, more mobile young became impaled and died in prickly pear *Opuntia* cacti in the confusion elicited by disturbance events. Disturbance early in the breeding season often had a lasting effect, with the disturbed sub-colony abandoned or remaining only thinly occupied throughout the remainder of the breeding season.

Severe population declines can result from excessive human visitation as exhibited on Isla San Martin, Baja California (Anderson & Keith 1980). In 1969 the breeding colony comprised 800 pelican pairs but declined rapidly in response to disturbance and pollution. Ecotourist visits occurred almost weekly throughout the early (most sensitive) breeding period, especially after 1972. At this time lessening pollution may have led to expected recovery but disturbance continued and by 1975 the colony had been extirpated.

Common eider *Somateria mollissima*

Bolduc and Guillemette (2003) investigated the effects of frequency and timing of disturbance, and the abundance of nearby avian nest-predators (great black-backed gull *Larus marinus* and American herring gull *L.*(*argentatus*) *smithsonianus* on eider nesting success at Michigan National Park Reserve, Quebec, Canada. Some 3,500 nests were surveyed on islands only rarely visited by recreationists during the nesting period. Three disturbance treatments were applied to a sample of nests and the incubating female: high frequency visits (once every three days) or low frequency visits (once every 15 days) commencing early in the incubation period; and high frequency visits starting late in the incubation period. A disturbance to each nest included flushing the female off the nest. Visits were designed to simulate tourists or researchers walking through a nesting colony. Disturbance treatments and nearby gull nest density had a significant effect on eider nesting success. The authors suggest that the main consequence of disturbance was to produce opportunities for gulls to predate unattended eggs, although no predation data is presented. Probability of nesting success was similar under the high and low frequency early-season disturbances (0.32 and 0.43 respectively). In contrast, high frequency visits starting later in the season resulted in a significant higher nesting success probability (98%) than the high

frequency early treatment. Most nest failures occurred after the first disturbance for all treatments but was lowest for the high frequency late disturbance treatment (11% dropping to almost zero on subsequent visits), compared to high frequency early visits (26%) and low frequency early visits (33%). In the latter two treatments a small decrease was noted over the next 2-3 visits of around 5%. The authors therefore recommend that visits by researchers/wildlife managers to eider colonies should be as late as possible in the incubation period, and visits should be avoided to colonies associated with high densities of potential egg predators. In terms of this present study therefore, visitation to nesting areas by walkers should likewise be avoided at such times in similar situations.

Keller (1991) observed that female eiders and their ducklings on the Ythan estuary in Scotland were frequently disturbed by recreational activities, both when onshore and when feeding in the water. Fishermen, people walking along the shoreline and dogs, caused more disturbances than water-based activities (windsurfers and rowing boats). Disturbance affected eider crèches (ducklings and attending females) for up to 35 min, presumably resulting in energy expenditure and loss of foraging time. Disturbance of small ducklings led to increased predator encounters (mostly large gulls) as ducklings were sometimes split from the adult females following disturbance events.

Eurasian oystercatcher *Haematopus ostralegus*

Tratalos *et al.* (in prep.) undertook an intensive survey of coastal beaches of Norfolk and Suffolk (southeast England), mapping locations of nesting oystercatchers and common ringed plovers *Charadrius hiaticula*. This coastline is a popular tourist destination, particularly in the summer when several species of wader, gulls and terns are attempting to breed. During the summer, on three days of peak human beach use (hot sunny days) the distribution and numbers of people were plotted (via video from a light aircraft). Taking into account habitat factors, results indicate that human disturbance on these beaches influence territory choice of both oystercatcher and ringed plover which select territories where human disturbance is relatively low, both at the scale of the whole Norfolk and Suffolk coast, and within areas of this coastline.

Verlust *et al.* (2001) undertook two short experiments to quantify effects of human disturbance on foraging and parental care of oystercatchers on Schiermonnikoog, an island in the Dutch Waddensea. In the first experiment conducted over three days, incubating pairs were disturbed on their mudflat feeding territory. The first and third days acted as controls (no disturbance), whilst on the second day, use of the feeding territory was prevented from 2 h before until 1 h after low tide by approaching feeding birds. Disturbance significantly reduced the proportion of time that eggs were incubated. In the second experiment, foraging adults with chicks were disturbed by two observers seated on the mudflat at different distances from the edge of the saltmarsh where the chicks were present. Total food collected by adults was independent of disturbance but a smaller proportion was allocated to chicks as disturbance levels increased. Both experiments indicate that human disturbance of foraging adult oystercatchers reduces the amount of parental care, which may in turn affect reproductive success.

African oystercatcher *Haematopus moquini*

Hockey (1997) considered that recreational disturbance may contribute to population declines of this near-threatened species, endemic to Namibia and South Africa. African oystercatchers tend to nest on beaches (many now popular with people) where nests are vulnerable to destruction through trampling and being run-over by vehicles, and eggs and chicks may be predated by domestic dogs. Disturbance can also result in drowning of chicks and loss of adult foraging time (Lambeck *et al.* 1996). Summers and Cooper (1977) also recorded that egg predation by gulls occurred when oystercatchers left there eggs unattended as a result of human disturbance. Hockey (1983) in a study of 55 oystercatcher pairs breeding on Marcus Island (South Africa), found that egg losses were high, primarily due to predation by kelp gulls *Larus dominicanus*. As observed in earlier studies, predation was exacerbated by human disturbance which forced incubating birds from their eggs.

It was thought that disturbance might also result in adults having insufficient time to satisfy their own and their offspring's food requirements. To this end, Leseberg *et al.* (2000) undertook a study to test if affects of foraging disturbance might vary regionally in response to variation in foraging conditions. Foraging times of adult oystercatchers were recorded at four protected areas (spanning 750 km of the South African coast) that experienced little or no human disturbance. Time spent foraging per day increased from west to east, paralleling a west–east decrease in intertidal primary productivity and biomass of grazing invertebrates (potential oystercatcher prey). There was also a west–east decrease in oystercatcher density. At two sites (De Hoop and Goukamma) where food intake rates are relatively low, oystercatchers regularly experience difficulties rearing two chicks under undisturbed conditions (only 19% and 8% of pairs rearing two chicks). It is thought therefore, that their ability to rear even a single chick could be compromised by even fairly low disturbance levels. At both sites, oystercatcher numbers have increased in recent years (up by 30% at De Hoop over 14 years, and 57% at Goukamma over nine years) corresponding to a reduction in human disturbance; at De Hoop in 1986 angling, bait-collecting and use off-road vehicles on beaches was stopped, and at Goukamma in 1990, bait-collecting, night-time shore angling and use of vehicles associated with commercial oyster harvesting was halted. Fledging success was also noted by Hockey (2002) to be generally higher in such protected areas.

Jeffery and Scott (2005) studied the breeding success of African oystercatcher on a 12 km section of coast west of Cape Agulhas (South Africa) from 1978 to 2002. An average of 15.9 (± 4.5) pairs bred per year with a significant increase over the study period despite a decline in nesting success, this decline attributed largely to increased use of off-road vehicles on beaches (and perhaps also the result of a natural cycle). Of relevance to this review is the behaviour of birds as a vehicle approached a nest, stopped and people alighted. Oystercatcher pairs were observed to be little affected by a vehicle (often not moving from a nest even if passed within 2 m) unless it stopped and people stepped out. Some pairs moved higher up the beach and re-nested, apparently to avoid more disturbed areas. There were few observations of direct impacts due to access on foot, but at least two nests were trampled. The greater ownership of off-road vehicles has led to greater ease of access to remote beaches, and this, along with associated people walking or undertaking other recreational activities may be impacting breeding success. Tourism and coastal

development are growing which could have long-term implications - high adult survivorship makes census data alone a poor predictor of future population trends, with productivity probably declining due to increased recreational disturbance (Hockey 2002).

Common ringed plover *Charadrius hiaticula*

Tratalos *et al.* (in prep.) undertook a survey of the Norfolk and Suffolk coastline (southeast England) of beach-nesting common ringed plover and Eurasian oystercatcher (see Eurasian oystercatcher account, above, for further details). Results indicate that human disturbance influences territory choice, both species establishing territories where disturbance is relatively low, although habitat features were also critical For ringed plovers this effect was shown to occur at small scales, with a negative relationship between numbers of visitors and presence of plover territories even when sections not containing or adjacent to an occupied section were excluded from analyses.

Liley (1999) undertook a 3-year study investigated the consequences of human disturbance for ringed plover populations along the west coast of Norfolk. Human disturbance, largely attributable to holiday makers, was especially concentrated around car parks (points of beach access) over two weekends in May (extended weekend holiday periods), and during July and August (school holidays) at the end of the plover breeding season. Disturbance came mostly from walkers (with or without dogs), sun-bathers and occasional picnickers, anglers and bait-diggers. Highly disturbed sections of beach were avoided by most nesting pairs (with the exception of those with no prior experience of breeding on the site) despite presence of otherwise suitable habitat. Where nesting occurred, density of territories and nests was less along more disturbed sections. Of all nests found, 8.5% were lost due to people, mostly (83.5%) though accidental trampling of the well camouflaged eggs, with a higher proportion of losses occurring closer to footpaths. An experiment with dummy nests revealed that 23% were lost to trampling, with more trampled where the density of people was higher. Disturbance did not affect incubation length, proportion of nests that hatched, or chicks fledged, although only low disturbance areas were considered. Chick foraging time was reduced in areas with more people but this had no effect on growth or survival to fledging, but whether this had any other impacts e.g. on chick fledging weight and subsequent longer term survival, is not known. A model was constructed that predicted that if human activity was restricted (e.g. through fencing of sections of beach with nests) then the ringed plover breeding population size would increase by about 8%, whilst if people were absent altogether the population would increase by around 85%.

In order to gain an insight into the effects of human disturbance, Rooney and Eve (1993) monitored 10 ringed plover nests on the north Norfolk coast over three days (the May Bank Holiday period) on a beach which traditionally experiences high numbers of tourists. When a person approached to within 100 m most plovers reacted by leaving the nest. For long periods there were constantly people within 100 m of all 10 nests. If people sat quietly within 50 m of a nest, especially if partly concealed by sand dunes, an adult would return to incubate. However, most visitors comprised family groups, and quiet recreational activity, giving plovers the opportunity to recommence incubation, was rare.

Pienkowski (1984) undertook a study of breeding ringed plovers at Lindisfarne, northeast England. Clutch survival to hatching was highly correlated with disturbance at three study sites over two breeding seasons. Nest survival averaged 50% in an area with around five human visitors/day, 27% in an area with up to 50/day, but only 1.7% in the area experiencing over 100/day. Unintentional disturbance by visitors and their dogs (see 5.4 Domestic dogs and disturbance) was considered more serious than direct loss (e.g. through trampling) as incubating birds normally ran from nests when approached, giving opportunities for carrion crows *Corvus corone* and other avian predators, watching for plover movement, to locate and predate the eggs. It was noted that increased movement to and from nests by ringed plovers due to disturbance, left tracks on sandy substrate leading to the nest scrape, and also possibly scent trails that mammalian predators (e.g. red fox *Vulpes vulpes*) might exploit.

Piping plover *Charadrius melodus*

There have been many studies looking at the effects of human disturbance on piping plover, a rare and declining North American wader. Concentrations of people appear to deter them from using otherwise suitable habitat. In Massachusetts, Hoopes (1993) found 95% of piping plovers (n = 209) occurred in areas that contained less than one person per 8,100 m² of beach. Elias-Gerken (1994) found that on Jones Beach Island, New York, piping plovers nested on stretches of beach with less pedestrian disturbance compared to where no plovers nested. On nearby Rhode Island, sections of beach were colonized by piping plovers within two seasons of their closure to heavy pedestrian recreation (Blair & Kurth, *in* Anon. 1996, U.S. Fish and Wildlife Services).

Lauro and Tanacredi (2002) investigated reasons for piping plover nest and chick loss at Breezy Point, New York, over five breeding seasons (1992-1996). The focus was to determine predatory pressures on breeding birds, as predation was known to be a serious problem at this site. The reasons for egg loss were often unknown (68%) but those identified were tidal flooding (2%), human disturbance (4%) and predation (26%) primarily by crows *Corvus* spp. and gulls *Larus* spp. The human disturbance data is unfortunately difficult to interpret; all 20 cases of egg loss attributed to people occurred in one breeding season (1994) but the actual causes (other than 'human') are not stated. National Parks staff managed the beaches during the study period, fencing of some stretches and imposing restrictions on bather and vehicle access, but other forms of potential human disturbance are not described.

Burger *et al*. (1995) (after Burger 1987, 1990, 1991) constructed a model to illustrate the effects of people on foraging activity of breeding piping plovers and parental care using data from three beaches on the New Jersey coast (USA). Observations showed that as the number of people within 10 m of a foraging adult plover increased, the time spent feeding decreased whilst 'alertness' increased; they also avoided sections of beach where people were present. The model suggests that with increased human presence adults have difficulty in finding sufficient food as foraging is disrupted. This in turn reduces the time for egg or chick defence. Further, when a person approaches an adult piping plover with young, they perform distraction displays whilst the chicks run and hide. As a result, if the brood is more than a single chick, parents have difficulty keeping their offspring together,

bringing with it associated problems. The authors suggest that because of the detrimental effects on productivity, closure of sections of beach to exclude people and their dogs during the breeding season may be the only option to enhance breeding success.

Flemming *et al.* (1988) undertook observations of piping plover on breeding beaches in Nova Scotia (Canada) to assess responses to human disturbance. The study population was 66-71 pairs in 1983, declining to 48-54 pairs by 1987. Since piping plovers are relatively long-lived and site faithful, the authors suggest that continual low fledging success was probably responsible for this population decline, rather than birds simply moving to other areas to breed. The low fledging success was considered due, in part at least, to human disturbance. Levels of disturbance were quantified over five years (1979-1983) by recording positions of people, their footprints and vehicle tracks. It was found that parents brooded chicks less when disturbance was higher, and responded to approaching humans at a higher level than other potential predator and non-predatory species. Increased disturbance led to fewer chicks surviving to fledging (17 days old). The number of chicks surviving/nest attempt was 1.8 young/pair in areas of low disturbance compared with 0.5 in areas of high disturbance. When people approached closer than around 160 m, chicks spent less time feeding, and when they did feed it was at a lower rate (5.7 pecks/min when disturbed, 12.5 pecks/min when undisturbed). Cairns (1982) reported that plover chicks in Nova Scotia that failed to achieve 60% of their normal body weight by day 12 were unlikely to survive to fledging, and Loegering and Fraser (1995) demonstrated that reduction in foraging time and foraging efficiency may be critical for chick survival. Goldin and Regosin (1998) studied piping plovers at Goosewing Beach, Rhode Island during 1993 and 1994. Broods with access to salt-pond mudflats experienced higher fledging success (3.0 fledglings/brood) than those limited to ocean beachfront habitat (1.4 fledglings/brood). This difference may have been due to the mudflats affording better foraging opportunities. However, broods on the mudflats spent less time responding to human disturbance (1.6%) than chicks on the more disturbed beachfront (17%) which also impacted on available foraging time. Whether the difference in time spent feeding between the mudflats (78%) and beachfront (51%) habitats affected fledging success is unknown.

Recreational use is often cited as a probable factor in preventing this species from nesting (e.g. Bowles *et al.* 1981, Flemming *et al.* 1988) and preservation of nesting habitat and protection from human disturbance during the breeding season are considered important to maintain and re-establish piping plover populations.

Kentish plover *Charadrius alexandrinus*

Schulz and Stock (1993) studied a 90 ha area of beach and dunes used by breeding Kentish plovers in Schleswig-Holstein, northern Germany. The area was heavily used by people, apart from a 12 ha protected area within a National Park. Over one breeding season (1990) plover nests were monitored and habitat variables recorded. The number and position of people mapped on 50 of the busiest days throughout the breeding season was used as a measure of disturbance intensity. The areas of habitat considered to be the most suitable plover breeding habitat were those most heavily used by people; as a consequence large areas were not settled and most nests were situated away from such areas. In this breeding season, 120 plover pairs made 178 breeding attempts. Of the 130

nests located the outcome of 101 was known; 66 were successful, 35 failed. In areas with high recreational disturbance clutch loss (36%) was much higher than areas of low disturbance i.e. in a protected zone with restricted access (10%). In the study area, walkers mostly followed the high tide line and thus rarely approached nesting areas, but may have disrupted foraging activity. Resting people (e.g. picnickers and sunbathers) tended to cause more disturbance as they were located in the proximity of the nests higher up the beach. Nesting success was also influenced by vegetation cover in areas heavily used by tourists, with a much higher rate of failure (50%) in sparsely vegetated areas compared with those nests in dense vegetation (14%). The authors suggest that as more nests in open areas failed, this indicated that aerial avian predators were likely to be the main cause of losses, with the increased human disturbance making it easier for predators to locate nests.

Snowy plover *Charadrius nivosus*

Ruhlen *et al*. (2003) examined the rate of snowy plover chick loss at different levels of recreational disturbance on beaches in Point Reyes National Seashore, California, USA. During weekends and holidays (chick exposure days: 319 weekend/holiday days vs. 505 weekdays in 1999; 216 weekend/holiday days vs. 364 weekdays in 2000) when human beach visitation increased, chick loss was 72% greater than expected in 1999 and 69% greater than expected in 2000. Over the two years, average chick loss was 65% during weekends and holidays but only 35% on weekdays. This suggests that increased human visitation negatively affected chick survival, although how this did so was not determined.

Lafferty *et al*. (2006) looked at the effect of reducing human access on the beach at Coal Oil Point Reserve (California) where snowy plovers had bred up to the late 1960s, but ceased to do so (apart from occasional nest attempt) when it was opened for public recreation. In June 2001 a 280 m stretch of dry sand was roped off (with people still allowed to walk past on wet sand close to the water's edge and requested to keep dogs on a lead) and a single pair successfully bred. The roped off area was increased to 400 m in length in 2002, and expanded further in 2003-2004 to protect nests outside the 400 m boundary. In response, disturbance incidences during the breeding season (recorded as a run/move or flight in response to a person or dog) fell by over 50%. Dummy nests in 2002 showed that the probability of egg loss to trampling was 8.1% outside the roped area and 0% within it. Numbers of breeding pairs, nests, eggs and young fledged increased each year following protection (five pairs fledging 14 young in 2002, rising to 26 pairs fledging 74 young in 2004). The initiation of breeding following protection strongly implies that a reduction in human and dog disturbance encouraged snowy plovers to return and breed.

New Zealand (dotterel) plover *Charadrius obscurus*

Lord *et al.* (2001) looked at the affect of deliberate human approaches to 15 pairs of beach nesting New Zealand plover (North Island subspecies *C. o. aquilonius*) during one breeding season. Three different approaches were undertaken: walking, walking with a dog on a lead, and jogging. Of these, walking with a dog was found to cause most disruption, with incubating birds flushing significantly earlier and remaining off the nest for significantly longer (see also 5.4 Domestic dogs and disturbance)**.** There were indications of some habituation to human activity, with birds nesting on high-use beaches

consistently showing a tendency to allow a closer approach before flushing and staying off their nests for shorter periods than birds nesting on remote beaches. Chicks also spent less time foraging when people were nearby, the assumption being that this could affect survival if they were unable to compensate for lost feeding time, and if they failed to achieve a suitable body weight this could prevent successful fledging, as supported by several studies of other shorebirds e.g. piping plover (Cairns 1982).

Hooded (plover) dotterel *Thinornis rubricollis*

Dowling and Weston (1999) monitored the population of hooded dotterels over seven breeding seasons along the Mornington Peninsula National Park coast, Victoria, southeast Australia. The area is heavily used by people, activities on the beaches including swimming, surfing, sunbathing, fishing, jogging and walking (including with dogs on a lead in permitted areas, although often dog walkers ignored the restriction and let dogs run free). A total of 171 nests were located and of these, by far the main cause of hatching failure was loss of clutches due to trampling by people with 53 (30%) of nests lost in this way. The other causes of known egg loss were red fox predation, flooding, and abandonment (just under 2% of nests each), whilst 40% of nests hatched successfully. The highest proportion of nests trampled were on the beach (51%) where human activity was concentrated, but trampling was also high in dunes behind beaches (21%) where 'dune boarding' was becoming increasingly common. Of 128 chicks monitored, 27% fledged but the causes of mortality although unknown, was partly attributed to dogs (see also 5.4. Domestic dogs and disturbance).

Weston and Elgar (2005) examined the causes and consequences of disturbance to hooded dotterel chicks from Johanna Beach to Oberon's Bay on the coast of Victoria. The main source of disturbance was from humans (81%), mostly people walking along the beach without a dog (57%) sometimes with a dog on a lead (2%) or off lead (15%), and also joggers (7%). In response to human approach, brood-rearing adults usually led their chicks away and either watched from distance whilst the chicks lay hidden (on the beach or in the fore dunes), or used aggressive or distraction displays. It was thought that adult brood defence might be compromised by human disturbance but there were no observations of any incidences of predation by avian predators (the most abundant potential predators present) during disturbance events. The number of minutes a chick spent hiding per hour was higher (30 min) during relatively disturbed days (weekends and holidays) compared with relatively undisturbed days during the week (22.5 min). The time chicks spent foraging per hour was also lower on relatively disturbed days (12.5 min) compared to relatively undisturbed ones (19.4 min). There was also a tendency for broods to forage along lower parts of the shore (potentially with greatest food availability) when undisturbed. It was considered that as well as impeding food uptake due to interruption of foraging, the run and hide response of chicks was also probably energetically costly. Adults brooding chicks exhibited a 31% reduction in brooding time in response to human activity; some chicks went unbrooded due to disturbance for up to almost 5 h and were exposed to temperatures of 10 to 46˚C, whether this caused thermal stress is not known. At this locality disturbance from humans was more frequent than that from natural causes. No direct link was established between human disturbance and

reduced reproductive success, but the mechanisms by which this could come about are demonstrated.

Least tern *Sterna antillarum*

Burger *et al*. (1995) evaluated the effects of ecotourism on several species of birds in coastal New Jersey, USA. At colonies of least tern they assessed breeding success relative to three types of human disturbance: primarily ecotourists; primarily other types of disturbance (e.g. sunbathers, joggers, walkers with dogs, anglers); and few ecotourists and few other disturbances. Overall, fewer birds nested and fledged fewer young per pair at colonies where ecotourists were prevalent compared to other colonies. However, it is difficult to assess the real affects of human disturbance at the respective study colonies as disturbance levels were not well quantified e.g. colonies visited by birdwatchers had more visitors generally than other beaches and were visited throughout the breeding season but whether with increased numbers of birdwatchers breeding success declined was not determined. Potential confounding environmental factors need also to be taken into account, e.g. colony location and natural vulnerability to predation.

Bridled tern *Onychoprion anaethetus*

Gyuris (2004) examined the impact of recreational visits on breeding sooty terns at Rocky Islets National Park (Great Barrier Reef World Heritage Area), Queensland, Australia. Two levels of human disturbance were implemented at five sites over three breeding seasons. In the first year, there was no disturbance other than minimal routine monitoring and this was used as a general control. In the subsequent two years, experimental disturbance at three sites commenced when 50 nests had been found. Disturbance regimes were designed to simulate low to moderate levels of visitation experienced on many Great Barrier Reef islands. Three variables were examined: hatching success; chick weight; and bill length at 12-13 and 21-22 days (fledging age) old. Hatching success was higher and chick weights significantly heavier at 12-13 days at sites exposed to greater levels of disturbance. The author suggests that these results indicate that early development of chicks may be adversely affected by disturbance but that such affects may be ameliorated by habituation to human intrusion into nesting areas. Habituation is a reasoned assumption as bridled terns use the same nest sites each year thus the birds in this study were repeatedly exposed to human presence. That they may have become habituated to some degree is backed by other observations. For example, in a study of common terns *Sterna hirundo*, Nisbet (2000) observed that the birds exhibited pronounced signs of tolerance by the middle of the second season of exposure to researcher disturbances.

Heermann's gull *Larus heermanni*

Anderson and Keith (1980) assessed the effect of human disturbance on productivity of Heermann's gulls in Baja California, Mexico. Censuses in 1974 at two colonies representing three disturbance intensities indicated that the number of young (expressed as young/100 full-breeding adults) was detrimentally affected by disturbance (no disturbance 17.7 young; moderate disturbance 13.6 young; heavy disturbance 4.5 young). Human intrusion induced massive 'confusion' within a colony with territorial

displacement of adults and young resulting in egg destruction and death of young caused by neighbouring gulls.

American herring gull *Larus smithsonianus*
Hunt (1972) looked at herring gull reproductive success on four islands in Penobscot Bay, Maine, northeast USA. Disturbance was measured on the basis of the number of old fireplaces, beer cans and picnic groups encountered during visits. Hatching success was lower in gull colonies frequented by more picnickers, regardless of proximity to prime foraging sites. Hatching success averaged 22% over two years at the two disturbed colonies and 48.5% at the two undisturbed colonies. It is suspected that when the adults were flushed, eggs were left exposed and overheated, causing embryo death. Unattended eggs were also predated by other gulls. However, chick rearing success was similar, with 40.5 and 35.5% successfully fledged at the disturbed and undisturbed colonies respectively.

CLIFFS
Common guillemot *Uria aalge*
Beale and Monaghan (2004) developed a model of perceived predation risk to help understand the effects of human disturbance on two cliff-nesting birds. The model predictions were tested using field data on nesting success of common guillemot (and black-legged kittiwake *Rissa tridactyla*; see below) at St. Abbs Head National Nature Reserve (Scotland) during the 2002 breeding season. On the cliffs 241 nests were selected and observed daily. Lay date to within two days, hatching and fledging success, and the number of people passing by were recorded. Manipulations of people consisted of allowing access to usually inaccessible areas (e.g. fenced off zones) or increasing numbers at viewpoints, assisted by volunteers for this purpose. Nest success was 70% with most failures (62%) during the egg stage. It was correlated with both people load (i.e. average index of people min/h divided by distance from the two nearest viewpoints) and average distance. Overall, the presence of people had a strong negative affect on nesting success. The model suggests that increasing visitor numbers by only 8.5% resulted in a 13% increase in failure rate, while halving visitor levels resulted in a nesting success of 87%. When people load was kept constant, nesting success was negatively correlated with the average distance people were from nests.

Schauer and Murphy (1996) found that when people approached nesting guillemots, accidental dislodgement of eggs occurred as adults were flushed from rock ledges, and predation of eggs, mainly by glaucous gull *Larus hyperboreus*, occurred when adults left eggs unattended when disturbed. Most predation appeared to occur early in the breeding season when human disturbance was highest and adult guillemots seemed most likely to temporarily abandon their egg.

Black-legged kittiwake *Rissa tridactyla*
In addition to guillemots Beale & Monaghan (2004) looked at the effect of human disturbance on kittiwake breeding success. A total of 106 nests were selected (see guillemot account, above, for disturbance methods) of which 42.5% successfully fledged

at least one chick, with most failures (59%) occurring during the chick-rearing (as opposed to incubation) period. Overall, nesting success was strongly related to the presence of people. The model suggests that increasing visitor numbers by 8.5% resulted in a decline in nesting success to 29% (a 22% increase in failure rate) while halving visitor levels resulted in a nesting success of 96%. When people load was kept constant, the average number of people minutes per hour was positively correlated with nesting success, whilst the distance these people were from the nests was negatively correlated.

However, the model does not take into account habituation to human disturbance which might be expected to occur in this species; some kittiwake colonies are remarkably tolerant of disturbance with breeding success appears little affected by it. For example, one long term study on the island of Røst (Lofoten Islands), Norway (pers. comm. Tycho Anker Neilson & Tomas Aarvark 2006) involves a population of kittiwakes nesting on buildings. People walk by many occupied nests to within 1-10 m during everyday activities. During the course of occasional additional disturbance caused by research activities (e.g. to ring birds), displaced adults or those caught and temporarily removed for a few minutes rapidly return to nests upon release (pers.obs.) and breeding success appears unaffected. Sandvik and Barret (2001) found that despite extensive researcher disturbance of nesting kittiwakes (again in Norway) any effects were small, although adult nest attendance decreased and daily chick loss rates were slightly higher. Overall chick survival until day 18 (around fledging) was significantly lower in the first than in the second year of the study. The authors suggest that a reduction in herring gull *Larus argentatus* predation as a consequence of disturbance was responsible (gulls nesting nearby were more susceptible to the effect of disturbance than the kittiwakes themselves); kittiwake habituation to disturbance may also have been a factor.

Peregrine falcon *Falco peregrinus*

Brambilla *et al.* (2004) aimed to assess the significance of rock climbing-induced disturbance and/or raven *Corvus corax* occurrence on breeding productivity of cliff-nesting peregrines in the provinces of Varese Como and Lecco, northern Italy, and Canton Ticino in southern Switzerland. Breeding success was recorded over one breeding season in 2002 at known breeding sites. Pairs (14) that nested on cliffs undisturbed by climbers and in the absence of ravens had the highest breeding success, fledging on average two offspring per territory. Conversely, on five cliffs where both climbers and ravens were present no young were fledged, this being tentatively attributed to raven predation of eggs/chicks due to attending peregrines being scared away by the presence of climbers. There were only two peregrine pairs in this study found nesting on cliffs frequented by climbers but with ravens absent, one of which fledged young; with such a small sample size it is not possible to draw any firm conclusions with regards the effect of climbers on peregrine reproductive success.

WETLANDS

Western marsh harrier *Circus aeruginosus*

Fernández and Azkona (1993) studied the effects of human disturbance on parental care by marsh harriers over one breeding season at Dos Reinos Lake, Ebro Valley, Spain.

They assessed changes in harrier reproductive activities and nestling nutritional condition in relation to low-level human disturbance. Six pairs (of 11) in the study area were observed daily and their behaviour compared in disturbed and undisturbed periods. The number of food items delivered by the male to the female, and the time spent by parents in the nesting area and on the nest itself, decreased during disturbed periods especially during incubation, whilst behaviours considered to be related to stress (alarm calls, chases against other birds intruding on the territory, and time spent flying) all increased 20-fold. Compared to the five pairs not subject to disturbance, productivity of the disturbed pairs (i.e. chicks fledged per pair) was not affected but their nestlings exhibited higher levels of blood urea (an indication of lower nutritional status). Of the 25 eggs laid by the six disturbed pairs, 16 chicks were successfully fledged (64%), whereas of the 24 eggs laid by the undisturbed pairs, likewise 16 chicks fledged (67%). The authors hypothesize that the minor human disturbances might reduce future breeding condition through increased expenditure of energy and time on non-reproductive activities, and reduced nestling condition may potentially affect subsequent survival after fledging.

Penny Anderson Associates (2003), collated observations during closure of parts of the countryside in the UK during the 2001 foot and mouth disease epidemic. Changes in marsh harrier nesting patterns were attributed to the lack of people and their dogs, with harriers nesting much closer to paths than usually recorded in several nature reserves in eastern England during the closure period.

HEATHS and LOWLAND GRASSLAND

Eurasian stone-curlew *Burhinus oedicnemus*

Taylor (2007) undertook a study of the effects of human disturbance on breeding stone-curlews *Burhinus oedicnemus* in Wessex, southern England. Recreational disturbance in the vicinity of breeding plots (blocks of farmland managed to provide suitable stone-curlew nesting habitat) during the early spring settlement period had a negative effect on plot occupancy. It was predicted that under current disturbance levels, removal of all recreational disturbance would result in an 11% increase in plot occupancy (equivalent to six extra plots occupied in the study area). Dog walkers were by far the most important disturbance factor, their removal alone resulting in a 10% increase in plot occupancy probability. Investigating the effects of human disturbance on breeding success over two breeding seasons, it was found that chicks grew more slowly on sites with disturbance but this had no influence on survival to fledging. No other significant effects were observed, suggesting that there are either few adverse impacts of disturbance on breeding success, or that stone-curlews selected to nest in less disturbed plots where the impact of low level disturbance on breeding success is not manifested. Evidence suggests that breeding pairs do in fact, select less disturbed areas. Observations of colour ringed adults after their arrival in spring, but prior to breeding, showed that 40% of pairs moved between sites before settling to nest. Pairs often moved if disturbance at the first potential nesting site was high, moreover, for pairs that moved, the second site chosen was significantly less disturbed. Pairs that moved bred, on average, a week later than those which did not move. This delay is considered likely to reduce the chance of producing a second brood, or re-laying in the event of clutch or brood failure.

European nightjar *Caprimulgus europaeus*

Liley and Clarke (2002, 2003) undertook an analysis of nightjar breeding densities on Dorset heaths in southern England. They found that there was no difference between the location of the centre of a nightjar territory and random points with respect to distance to roads or a heathland edge, but territory centres were significantly further away from the nearest built-up area (Liley & Clarke 2002). They went on to integrate existing data sets of factors potentially influencing nightjar numbers on 36 heathlands in Dorset. Although no observations of human disturbance were incorporated, surrogate disturbance measures, including the amount of developed land at different distances from the heath and the number of buildings, were used. These were highly correlated and showed a strong negative relationship with the density of nightjars present on a heathland patch, regardless of its size. The amount of surrounding woodland (a preferred nightjar foraging habitat) within 500 m of the edge of a heath was positively correlated with nightjar numbers and significantly improved nightjar density predictions. The study demonstrates that nightjar numbers on a heathland are influenced by surrounding land use, with sites surrounded by more development supporting lower nightjar densities, the effect of urban development is thus more than just habitat loss. The authors suggest that this is at least partly due to human presence on heaths, as it has been shown that people living close to heaths in Dorset regularly visit them, and that high levels of recreational use e.g. dog walking, are evident on some. They further suggest that where open access to heathlands is proposed in light of CRoW, access management to avoid deleterious impacts to nightjars need to be considered.

Murison (2002) looked at the impact of human disturbance (mostly dog walkers) on nightjar breeding success, also on Dorset heaths. In 2002, nightjar territories on 10 sites were mapped, as many nests as possible were located and monitored to fledging. Of the 47 nests found, 19 (40%) were successful and 28 (60%) failed (24 at the egg stage). Of those that failed, 93% were lost due to predation, mainly by corvids (63%), with nine (37%) attributed to mammals. There was a negative relationship between both density of nightjar territories and the proportion of successful nests (i.e. those producing at least one fledged young) on sites, with the number of buildings within 500 m of the site boundaries. Paths were categorised as low, medium or high use. Nests were more likely to be predated closer to paths, and the greater the length of high/medium use paths within 500 m of a nest, the poorer the breeding success. The results hint that human disturbance might increase predation, perhaps by flushing of incubating or brooding adults thus bringing to the attention of, and exposing them to predators. Although not quantified, dogs off leads (from anecdotal evidence from this and other studies) may flush adults and also occasionally kill chicks, but conversely dogs have also been shown to flush adults and approach eggs or chicks and leave then unharmed.

Woodfield and Langston (2004), looked at nightjar nesting success in relation to access levels on four heaths surrounded by developed land, all receiving high recreational use. During the 2003 breeding season, nests were located and monitored, eight by using video cameras. Ten (34%) of the 29 nests found, all at the egg stage, failed. Of the 19 that were successful, 32 young were fledged. Human visitation rates were recorded by undertaking

transect walks across the sites at hourly intervals during the day throughout the breeding season. Additional counts were made in the proximity of nests during peak visitor periods. The nest cameras recorded 12 flushing events of a sitting nightjar, one being flushed by a dog once whilst incubating, and again whilst brooding chicks, but the young fledged successfully. One flushing incident led to predation of the eggs by a carrion crow *Corvus corone*. It was calculated that the nightjars on these highly disturbed heaths had on average, a 12% chance of being flushed each day. All flushing events (the cause of which was not always known) were assumed to be caused by disturbance as nightjars do not leave the nest during the day otherwise. Similar to the results of Murison (2002), nesting success decreased with footpath proximity, and also decreasing vegetation cover around nests. However, due to the small sample sizes, none of these findings were statistically significant. Results from these latter two studies suggest that nightjars (which lay clearly visible white eggs) suffer greatest nest failure (36-86%) at the egg stage. The eggs are obvious if the camouflaged adult is flushed, and circumstantial and direct evidence points to predation upon flushing as being a problem.

Woodlark *Lullula arborea*

Mallord (2005) undertook a three year study investigating the consequences of human disturbance, urbanisation and habitat fragmentation for a woodlark population on heaths in Dorset, England. Across heaths, woodlark density per hectare of suitable habitat was lower on sites with higher levels of human disturbance (mostly walkers, many with dogs either on or off lead). Of heaths with recreational access, the probability of suitable habitat being occupied was lower in areas with greater disturbance - at around only eight disturbances an hour, occupation probability fell below 50%. A survey across 12 heaths in 2002 and 16 in 2003 showed that at low disturbance (<0.01 people/survey/ha) the density of woodlark pairs was around 0.6 pairs/ha of suitable habitat, whilst at the highest disturbance levels recorded (>0.1 people/survey/ha) woodlark densities fell to around 0.1-0.2 pairs/ha. However, woodlarks nesting on more disturbed heaths fledged more chicks per pair due to a greater density-dependent reproductive success throughout the breeding cycle, including recruitment into the local breeding population. This density dependent breeding success partially balanced the negative effects of disturbance, but it was calculated that there was a 34% reduction in productivity to that predicted in the absence of disturbance. A model was constructed that predicted that the impact on the woodlark population depended both on numbers of people and their distribution on the heaths. Under access arrangements at the time of the study (i.e. most people using footpaths and keeping to fairly defined areas), the model suggested that a doubling of visitors had little effect, whilst the same number of people distributed evenly across all sites (a theoretical scenario) led to a major negative impact on the population. This latter prediction however, exemplifies the importance of site management and perhaps restriction of access to some areas during at least the breeding season, and an obligation to keep dogs on a lead during this period for the benefit of ground nesting birds in general.

Liley and Clarke (2002) in a study of the impact of urban development around heaths, found no apparent effects of more surrounding developed land on woodlark territory density (used as a surrogate for human disturbance), but like Mallord (2005), showed that

there were fewer territories on sites with open access (higher disturbance area) compared with ones that were closed to the general public (lower disturbance areas).

Taylor (2002) conducted a nest predation experiment on a selection of Dorset heaths over one breeding season using clay eggs in artificial woodlark nests placed in typical woodlark habitat (but at higher densities than would naturally occur). There were three main significant trends recorded: corvid numbers increased at higher levels of human disturbance; nest predation increased as predator numbers increased; and predation increased at higher levels of human disturbance. The predation rate of the artificial nests was 69%, and where a predator could be identified 53% were corvids and 26% foxes *V.vulpes*. Predation was also higher in areas with less vegetation cover and shorter vegetation. However, despite being undertaken on the same study heaths as Mallord (2005), these predation rates bore no similarity to that found for real woodlark nests. Inferences that nest predation increases with human disturbance drawn solely from such artificial egg predation experiments should therefore be viewed with caution unless data on predation rates of real nests is also available.

Western meadowlark *Sturnella neglecta*; **Vesper sparrow *Pooecetes gramineus***; **Grasshopper sparrow *Ammodramus savannarum***

Miller *et al.* (1998) investigated the influence of recreational trails on breeding bird communities in forest and mixed-grass prairies in Boulder County, Colorado, USA over two breeding seasons. The area comprises agricultural land and areas reserved for recreation e.g. hiking, exercising pets, jogging, mountain biking, horse riding and wildlife watching. The intensity of recreational use is extremely high. In the grassland areas, nests of ground-nesting birds were located from the edge of trails out to 200 m, ensuring equal search effort at all distances (by dragging a rope across the ground). No nest abandonment was caused by this search method. Number and distance of nests from trails was monitored for 5 weeks in 1994 and 7 weeks in 1995. Control transects in grassland away from trails were also established, where three ground-nesting grassland species, western meadowlark, vesper sparrow and grasshopper sparrow, were found to be significantly more abundant than along trail transects. Western meadowlark and grasshopper sparrow were less likely to nest near trails. Nest predation of all three species was greater closer to trails. Probability that a nest in the grassland would survive one day (n = 163 nests; 1,954 nest days) was related to distance from trails; the further the distance from a trail, the higher the probability of survival. Overall, the results indicate that bird composition and abundance were altered adjacent to trails with some grassland specialists occurring in and nesting at lower densities near trails, and nest predation rates being higher closer to trails.

Dark-eyed junco *Junco hyemalis*

Riffel *et al.* (1996) over five breeding seasons (1989-1993) experimentally assessed whether repeated human intrusions resulted in cumulative impacts on birds in the Medicine Bow National Forest, Wyoming, USA. Repeated intrusions were made into 1 ha plots by a lone walker and the number and species of birds in these were compared with undisturbed control plots. Intrusions lasted 1-2 h each week over 10 weeks and were undertaken at two intensities: 1 or 2 days/week. Disturbance plots were radially walked

and any bird observed was approached directly. On approach birds were flushed from resting, feeding, singing or nesting areas. Declines in avian richness and abundance were tested for at the community, nesting guild (cavity nester; open-nester <2 m above or actually nesting on ground; open-nester nesting at >2 m above the ground) and species level. The average number of individuals on a site during a census during a given year was analysed for four common passerines, one of these being dark-eyed junco, a ground-nester. Relative richness and abundance were the only metrics to exhibit declines between years over the five study years. These declines however, were not cumulative and significant declines in abundance were not evident. Fourteen species fell into the understorey nesting guild, of which nine habitually nest on the ground or very close to it. No decreasing trends were evident in the mean percentage of controls for richness of migrant or resident understorey-nesting species. The authors suggest that cumulative declines were not apparent as individuals displaced one year may have been replaced in subsequent years, and some individuals may have become habituated to the disturbances. Therefore in this particular locality for those bird communities studied, they propose that management should focus on preclusion or amelioration of short-term disturbance impacts.

MOORLAND, TUNDRA and MOUNTAIN

Greater snow goose *Chen caerulescens atlantica*

Bêty and Gauthier (2001) assessed the effect of nest visits by researchers on the activity on nest predators and predation rate of eggs in a colony of greater snow geese in Nunavut Territory, northern Canada. Although this study involved deliberate nest visits, inferences can be drawn as to likely behaviour and outcomes if walkers were to pass through such a dispersed colony. The study was conducted in two breeding seasons, in years (1996) of moderate, and low (1997) nest predation rates in the region. In 1996 there was a small increase in Arctic skua *Stercorarius parasiticus* activity during nest visits compared to undisturbed areas but this was not apparent in1997. In 1996, activity rate of another potential avian predator, glaucous gull *Larus hyperboreus*, was no different between disturbed and undisturbed conditions, but in 1997 activity and time spent in the colony was 11.9 times higher during nest visits compared to undisturbed conditions. There was no significant effect of investigator presence on the activity of common ravens *Corvus corax*.

Around 10% of predator observations in the colony involved in attacks on goose nests but the impact of researcher disturbance was different in each year. In 1996 the probability of attack tended to be lower during visits but the difference was not significant, whilst in 1997 the probability that a predator attacked a nest was 4.8 times higher during nest visits. However, the number of successful attacks (eggs predated) was low in both years. In 1996 only two of four observed attacks during visits were successful, compared to five of 17 in undisturbed conditions. In 1997 there were three successful attacks out of 11 and zero out of five respectively. In addition, there were no significant differences in average clutch size at the end of incubation or nesting success between nests that were visited eight times compare with those visited three or less times. This study showed that nest visitation had very little impact on snow goose productivity but the authors suggest that

this may not be the case for many arctic birds that, unlike the large and potentially aggressive snow goose, might not be able to ward off predators as effectively, especially in years when availability of small mammals is low, and predation pressure on breeding birds correspondingly high.

Black grouse *Tetrao tetrix*
Baines and Richardson (2007) experimentally assessed the potential effects of human disturbance on back grouse in the North Pennines, northern England. In the UK, black grouse (threatened status) are potentially at risk from increased human recreational disturbance due to statutory right of human access recently granted through the CRoW Act. Between 2002 and 2004, 77 black grouse were caught and radio-tagged. Each was randomly assigned to one of three disturbance treatments of simulated recreational hiking by approaching individual birds until they were displaced: no disturbance (low), fortnightly disturbance (moderate) or twice weekly disturbance (high). Birds disturbed more regularly flushed at greater distances. There were however no differences in fecundity (clutch size, hatching success, breeding success) or survival, between treatments. The experimental disturbances had no discernible impact upon the black grouse populations in the study areas. It is emphasised that this it not to say that more frequent disturbance might have an impact.

Potential negative impacts of dogs on breeding females have already been partially mitigated within the Act, which stipulates that dogs should be restrained on short leads between 1 March and 31 July.

Red grouse *Lagopus lagopus scoticus*
Watson (1988) recorded declines in Scottish red grouse populations associated with the presence of people. These declines were however, not attributed to human disturbance directly but in response to increased corvid numbers attracted to the area by waste food left by visitors. The presence of more crows led to greater predation of grouse nests.

Common sandpiper *Actitis hypoleuca*
Yalden (1992) looked at the influence of recreational disturbance on common sandpipers breeding around a large upland reservoir in the Peak District National Park, England. During weekends throughout the 1989 and 1990 breeding seasons, sandpiper and angler censuses were undertaken around the entire shoreline. More detailed behavioural observations of a few breeding pairs were also made. Anglers were present throughout the breeding season, with numbers tending to be higher (40-79) in April-May, decreasing to around 25 by July. The highest count was equivalent to 7.8 anglers/km of shoreline, but they were not spread evenly; there were some popular angling beaches where nearest 'neighbour distances' were around 25 m. Sandpipers took flight about 29% more in areas with anglers and other visitors, compared with undisturbed shoreline stretches. These flights often meant that birds encroached onto adjacent territories resulting in far more territorial disputes. During 37.5 h of observation, adults with chicks were disturbed 59 times mostly (57%) by anglers or hikers. Other sources of disturbance were sheep and predators (e.g. corvids, weasel *Mustela nivalis*). Chicks hid upon disturbance from a single passing person for an average of 3.1 min, in one extreme case a passage of people

caused chicks to hide for 34 min. The normal pattern of behaviour is for chicks to be fed/brooded every 7-8 min; in some cases this was severely disrupted. When anglers or picnickers settled in a territory, parent sandpipers frequently tried to lead their chicks away, again often resulting in confrontation with neighbouring territorial pairs. In 1989 there were 31 territories, of which 21 (68%) hatched and 13 (42%) fledged young. In 1990 there were 26 pairs, 15 (58%) hatching and 13 (50%) fledging young. These overall densities (2.5-3 pairs/km) and productivity are comparable with the best river-nesting populations. The consequence of human disturbance for this sandpiper population was that they avoided using popular angling beaches. Based on approximately 6.5 km of shoreline and with 40 pairs in quiet sections (i.e. below average disturbance – visitor score of <6/km/visit), there should have been 24 territories along the 4 km of busy shore, but there were only 17, thus the breeding population size was constrained. However, breeding success (number of young fledged) of pairs was unaffected regardless of whether they nested in busy or quiet sections.

Eurasian golden plover *Pluvialis apricaria*

Finney *et al.* (2005) used data collected over 13 years to investigate the impact of recreational disturbance on the distribution and reproductive success of golden plovers close to a major long-distance footpath, the Pennine Way, in the uplands of northern England. Whether the response of golden plovers to recreational disturbance was influenced by changes in the intensity and extent of human activity could be examined as in 1994, to prevent further erosion of surrounding vegetation and soil, a section of the path (crossing the Snake Summit) was resurfaced. Prior to this resurfacing 32% of all people (including with dogs) strayed from the path to avoid severely eroded sections and movement across the moorland was widespread and unpredictable. During the chick-rearing period, the birds tended to avoid areas within 200 m of the footpath. At this time there were around 60 visitors/day at weekends and 20/day on weekdays. After resurfacing, most (96%) hikers remained on the path with a resultant significant decline in disturbance to the adjacent moorland. In response, golden plovers came much closer to the path, avoiding a band of about 50 m in width either side of it. The median distance from the path during five years (for which data was available prior to resurfacing) was 277 m, compared to 191 m for the five years after. The population size of golden plovers breeding within the Snake Summit study area doubled during the study period from an estimated 15 pairs in the late 1980s to 30 in the mid 1990s (Yalden & Pearce-Higgins 1997, Finney *et al.* 2005). Golden plover brood survival differed significantly between two study periods. In 1986-1988 prior to resurfacing 68% fledged, but in 1996-1998 after resurfacing only 46% fledged. However, there was no evidence of a relationship between brood survival and distance of the territory from the path. This study suggests that at the intensities of people recorded, there would be a zone of about 400 m width along an unsurfaced moorland path where golden plover occupancy would be reduced. Management measure, such as resurfacing, would help to reduce straying and creation of a network of smaller paths potentially being created, which might otherwise further exclude birds from suitable habitat.

Finney *et al.* (2004) undertook a similar study, again along the Pennine Way, on Saddleworth Moors using data collected in 1986-1988. This site was similar in terms of

habitat but visitor levels were one quarter of that (15 people/day at weekends) (Yalden & Yalden 1988) recorded at Snake Summit (60/day at weekends) and thus allowed a comparison of the effect of different disturbance levels on breeding golden plovers. As at Snake Summit, habitat and topography had an influence on golden plover distribution, but conversely there was no evidence that they avoided areas close to the path. The evidence therefore suggests that at this lower disturbance level, there was no significant effect on golden plover distribution during the chick-rearing period.

Overall, these observations indicate that in more popular areas, such as at Snake Summit, recreational activity could impact on golden plovers (and potentially other upland waders) by reducing the availability of suitable breeding habitat. It is thought likely (Finney *et. al* 2005) that the 54% drop in occupancy within 200 m either side of the Pennine Way (equivalent to 29% of the study site area), was sufficient to reduce golden plover breeding density. Subsequently, Pearce-Higgins *et al*. (2007) examined to what extent habitat avoidance is dependent upon visitor numbers at Saddleworth Moors, and found no evidence that golden plovers avoid disturbed areas where visitor pressure was half that previously studied. They also investigated whether the large numbers of visitors (120 per weekend day) using the surfaced footpath impacted on breeding success, despite the lack of habitat avoidance. There was no evidence that nest location, clutch survival or chick growth rates were reduced close to the footpath. These results suggest that high levels of disturbance can impact upon habitat usage, but only in limited circumstances where visitor pressure is very high (> at least 30 visitors/weekend day). The authors suggest that access to such areas can be permitted for large numbers of visitors without impacting upon wader reproductive performance through the provision of a well-surfaced path.

Yalden and Yalden (1989) used alarm-calling behaviour to estimate the sensitivity of adult golden plovers to walkers. The average distance at which they began alarm-calling in response to an approaching person was approximately 200 m during the chick-rearing period. This is the same distance at which the drop in golden plover occupancy was recorded by Finney *et al*. (2005). Finney *et al.* further suggest that for breeding waders, similar studies might indicate distances from disturbance sources over which habitat occupancy is likely to be reduced. For example, response distances include 50 m for dunlin (Yalden & Yalden 1989), 75 m for common sandpipers *Actitis hypoleucos* (Yalden 1992), 100 m for New Zealand dotterels (Lord *et al.* 2001), and over a 1 km for Eurasian curlew *Numenius arquata* and common redshank *Tringa totanus* (Yalden & Yalden 1989). If such alarm-calling behaviour is reflective of sensitivity and settlement during the breeding season, these distances suggest that the impact of recreational disturbance on breeding waders will vary depending on the species concerned.

Dunlin *Calidris alpina*

Finney *et al*. (2004) as well as studying the effects of disturbance on golden plover, also studied dunlin in the Snake Summit area of the Pennine Way using the same methods, during 1987-1988 and 1996-1998. Dunlin distribution was also monitored (1987-1998) over the spring bank holiday period at the end of May (traditionally a period of high human visitation, dependent on weather conditions). Use by dunlin of moorland within 200 m of the path increased by around 50% following resurfacing. The median distance

of dunlin from the path prior to resurfacing was 175 m, this reduced to 97 m following resurfacing. As there was no significant change in vegetation composition, this change in distribution was considered to be due to a reduction in disturbance, as following resurfacing most hikers kept to the path.

Pearce-Higgins *et al*. (2007) on Snake Summit, found that dunlin *Calidris alpina* habitat utilization in disturbed areas showed a non-significant increase of approximately 50% following the provision of a surfaced footpath, in a manner similar to that observed for golden plover.

Eurasian dotterel *Eudromias morinellus*

Watson (1988) looked at spring densities and breeding success of dotterel in relation to numbers of people and dogs on Cairn Gorm, Scotland. Over the 10-year study period (1971-80) human recreational activities increased. Dotterel densities were not correlated to density of people (which varied from 0.1-6.8/km²/count) or their dogs. Dotterel on their breeding grounds are very confiding and will allow a very close human approach to the nest before moving off, this behaviour thus perhaps accounting for this. However, in one area close to access roads and a chairlift that attracted many people, consequently suffering extensive vegetation damage and soil erosion, there was some evidence that dotterel avoided the disturbed ground. Watson observed crows *C.corone* occasionally predating nests. Crows were rare in this arctic-alpine zone prior to development of ski-lift facilities in the 1950s, but subsequently increased greatly in numbers attracted by food left by people. However, the evidence indicates that over the duration of the study, human impact had not reduced dotterel numbers or breeding success.

Whitfield *et al.* (in review) undertook a long-term study of breeding dotterel, also on the Cairngorm plateau. As many nests as possible were located, date of first laying, clutch size, hatching success, causes of failure and surrounding vegetation type were recorded. Distance to nearest footpath and off-path visitor use was used as surrogates for nest disturbance probability. Around 70% of people stayed close to footpaths, thus disturbance probability was considered higher closer to paths.

In total 211 clutches were found. Their location was unaffected by path proximity, later clutches were not further from paths and those nests close to paths were not of inexperienced pairs. Hatching and fledging success, and daily nest survival were unaffected by path proximity or density of people (albeit low) off paths. There was a trend towards poorer hatching success in areas with more people straying off paths but this was not significant. The causes of nest failure were determined for 76 clutches that failed to hatch. One clutch was thought to have been destroyed by a dog and two trampled by hikers but predation by natural predators, followed by desertion due to snowfall, were the main causes of failure. It is suggested that the high predation and desertion rates (accounting for over a third of losses of nests found) may have been due to walkers flushing birds from nests which attracted predators (e.g. common raven *Corvus corax*) to the nest or lead to desertion. However, due to their very confiding nature (often allowing a very close approach by a person to the nest before moving off) and that predation was not related to path distance or study area, strongly suggests that human disturbance through access on foot was not a main factor, if at all, in influencing predation rates or desertions. The study

further found that there was no correlation between post-fledging survival and nest distance from a path, and young returning and nesting the next year (identified by colour rings) were not significantly further from paths. Annual variation in dotterel density and breeding success were not correlated with numbers of people or their dogs. At levels of human disturbance observed during this study (concurring with Watson, 1988) dotterel breeding success in the Cairngorms appears little affected by human disturbance in this region.