CEE review 09-007

ARE MAMMAL AND BIRD POPULATIONS DECLINING IN THE PROXIMITY OF ROADS AND OTHER INFRASTRUCTURE?

Systematic Review

BENÍTEZ LÓPEZ, A.[1], ALKEMADE, R.[2] AND VERWEIJ, P.[2]

[1] Current address: Instituto de Investigacion en Recursos Cinegeticos (IREC, CSIC-UCLM-JCCM) - Ronda de Toledo s/n, E-13071 - Ciudad Real - Spain.

[2] Netherlands Environmental Assessment Agency (PBL) - PO Box 303 - 3720 AH Bilthoven - The Netherlands

Correspondence: ana.benitez@uclm.es
Telephone: +31 30 2748605 / (+34) 926 295 450 ext. 3377

Draft protocol published on website: 9 February 2009 - Final protocol published on website: 06 March 2009- Draft review published on website: 11 March 2009 – Final review posted on website: 25 February 2010

Cite as: Benítez-López, A., Alkemade, R. & Verweij, P.A. 2010. Are mammal and bird populations declining in the proximity of roads and other infrastructure? CEE review 09-007 (SR68). Collaboration for Environmental Evidence: www.environmentalevidence.org/SR68.html.

Summary

1. Background

Biodiversity is being lost at an increased rate as a result of human activities (Vitousek, 1994; Pimm et al., 1995; Sala et al., 2000; MEA, 2005). One of the major threats to biodiversity is infrastructural development (UNEP, 2001; Sala et al., 2000; Sanderson et al., 2002; Alkemade et al., 2009). The most commonly reported impacts from roads and utility corridors include habitat loss, intrusion of edge effects in natural areas, isolation of populations, barrier effects, road mortality and increased human access (Andrews, 1990; Forman and Alexander, 1998; Spellerberg, 1998; Trombulak and Frissell, 2000; Forman et al., 2003). Besides roads, other types of infrastructure, such as railways, powerlines, pipelines, hydroelectric developments, oil wells, seismic lines and wind parks, have an impact on wildlife populations (Dunthorn and Errington, 1964; McLellan and Shackleton, 1989; Cameron et al., 1992; Van Dyke and Klein, 1996; Mahoney and Schaeffer, 2002; Nellemann et al., 2003a; Barrios and Rodriguez, 2004). All these impacts may influence the long-term viability of populations and, eventually, biodiversity. In this study, we aim at estimating the decline of animal populations, in particular bird and mammal species, in relation to proximity to infrastructure by using a meta-analytical approach.

2. Objectives

To systematically collect and synthesize the available published and unpublished evidence in order to answer the questions:

- What are the impacts of roads and infrastructure on mammal and bird populations? What are the disturbance distances at which mammal and bird populations are significantly reduced?
- Do traffic volume, habitat, infrastructure type have an effect on the decline of mammal and bird populations in the proximity of roads?
- Are there any differences in the response of birds and mammals to infrastructure due to the study of different species populations?

3. Methods

Multiple electronic databases and web sites were searched using key words such as “road effects, infrastructure distance, road avoidance, etc”. Bibliographies of articles viewed at full text were searched for relevant additional articles. Researchers and experts were contacted to retrieve relevant material. One reviewer selected articles that met the selection criteria regarding subject, intervention, outcome and comparators. A second reviewer checked studies whose data suitability for the meta-analysis was unclear for the first reviewer. Disagreement regarding inclusion or exclusion of a certain study was resolved by consensus. Additionally, a statistician helped to solve problems regarding data extraction and variance inference for studies with insufficient information on standard deviation, standard error and/or sample size.

We selected studies included sufficient data to derive ratios by comparing bird and mammal species abundances at disturbance distances and at control distances. These ratios were combined in the indicator mean species abundance (MSA), used as the effect-size measure. The impact of infrastructure distance on MSA was studied by using meta-analysis in R 2.9.1. Possible reasons for heterogeneity in the results were explored by performing meta-regression of mixed effects (GLMM) in S-Plus 7.0. In these analyses MSA values were weighed by the inverse of their variances.

4. Main results

More than 600 references were reviewed at full text and identified as relevant for assessing the impacts of infrastructure on biodiversity. Of these references, a number of studies were left out of the analysis: studies on other taxa (reptiles, plants…), studies not reporting on densities or abundance of bird and/or mammal species, studies not containing proper comparators or control distances, studies whose data was not suitable for the calculation of the effect size and studies reporting on the impacts of human access and human activities from infrastructure. Finally we selected 49 studies from which we extracted 86 datasets on 234 mammal and bird species that were suitable for the meta-analysis. In these studies, the main response by mammals and birds in the vicinity of infrastructure was either avoidance or a reduced population density.

Mammal and bird population densities significantly declined with their proximity to infrastructure. Bird populations were reduced at a shorter distance to infrastructure than mammal populations. Mammals and birds seemed to avoid larger distances from infrastructure in open areas compared to forested areas, which could be related to the reduced visibility of the infrastructure in forested areas. We could not find a significant effect of traffic intensity on the MSA of birds. Species populations responded differently to infrastructure. Raptors were found to be more abundant in the proximity of infrastructure whereas the other bird taxa avoided it. Small-sized mammals were affected within few meters from infrastructure while abundance of large-sized mammals was reduced up to several hundred meters from infrastructure.

5. Conclusions

The available evidence from the meta-analyses and the meta-regression suggests that mammal and bird populations are displaced from infrastructure, and that displacement distance depends on the habitat type and on the species population. The findings of our analysis represent a step forward in the field of road (and infrastructure) ecology research that may contribute to the understanding of the magnitude of the pernicious effects of infrastructure development on animal populations.

Our findings show the importance of minimizing infrastructure development for wildlife conservation in relatively undisturbed areas. By combining actual species distributions with the effect distance functions we developed, regions sensitive to infrastructure development may be identified. Additionally, the effect distance functions can be used in models in support of decision making on infrastructure planning.

1. Background

Global biodiversity is changing at an unprecedented rate, as a result of several human-induced changes in the global environment (Vitousek, 1994; Pimm et al., 1995; Sala et al., 2000; MEA, 2005). Biodiversity loss at the species level tends to result in the so-called homogenisation process (Lockwood and McKinney, 2001). This process is generally characterised by a decrease in the abundance of many species, culminating into an increase in the number of threatened species and the extinction of others, in combination with a simultaneous increase in the abundance of a few species. The main drivers of biodiversity change are land-use and land-cover change, climate change, pollution, fragmentation and infrastructure development (UNEP, 2001; Sala et al., 2000; Sanderson et al., 2002; Alkemade et al., 2009).

The ubiquity of road networks and the growing body of evidence of the negative impacts that roads and other linear infrastructure have on wildlife and ecosystems suggest that infrastructure represents a major driving factor of biodiversity loss. The most commonly reported impacts from roads and utility corridors include habitat loss, intrusion of edge effects in natural areas, isolation of populations, barrier effects, road mortality and increased human access (Andrews, 1990; Forman and Alexander, 1998; Spellerberg, 1998; Trombulak and Frissell, 2000; Forman et al., 2003). Road construction leads to habitat destruction and creates open spaces in otherwise closed forests (Gullison and Harner, 1993; Reed et al., 1996; Santos and Tabarelli, 2002). The open spaces may fragment populations (barrier effect), attract light-demanding species and may be avoided by others (edge effect) (Kroodsma, 1984; Vos and Chardon, 1998; Bolger et al., 1997; Ortega and Capen, 1999). Additionally, the use of infrastructure by cars or trains increases the risk of collisions with wildlife and stress on (breeding) individuals (due to noise and visual stimuli), both of these risks affecting animal populations (Van der Zande *et al*. 1980; Reijnen et al., 1996; Romin and Bisonette, 1996; Boarman and Sazaki, 2005; Parris and Schneider, 2009).

Besides roads, other types of infrastructure, such as railways, powerlines, pipelines, hydroelectric developments, oil wells, seismic lines and wind parks, have an impact on wildlife populations (Dunthorn and Errington, 1964; McLellan and Shackleton, 1989; Cameron et al., 1992; Van Dyke and Klein, 1996; Mahoney and Schaeffer, 2002; Nellemann et al., 2003a; Barrios and Rodriguez, 2004). All these impacts may influence the long-term viability of populations and, eventually, biodiversity.

Qualitative reviews provide a broad understanding of the ecological effects of infrastructure that affect a range of taxa and ecosystems, but lack quantitative evidence (Trombulak and Frissell, 2000; Forman et al., 2003). However, the few attempts to quantify the effects of infrastructure (UNEP, 2001; Nellemann et al., 2003b, Fahrig and Rytwinski, 2009), or to model the vulnerability of animal populations to road effects (Jaeger et al., 2005), are not based on meta-analysis − which is the statistical procedure for combining the results of independent studies in a quantitative way (Arnqvist and Wooster, 1995). In this study, we aim at estimating the decline of animal populations in relation to proximity to infrastructure by using a meta-analytical approach.

Among all animal taxa, mammal and bird populations were chosen for our analysis since both have been widely reported to be declining in relation to their distance from infrastructure. However, large differences in disturbance sensitivity seem to exist between and within these groups. Bird populations seem to be affected within a few hundred metres from infrastructure, whereas a reduction in mammal populations has been found at distances of a few hundred metres up to several kilometres from infrastructure (McLellan and Shackleton, 1989; Cameron et al., 1992; Ortega and Capen, 1999; Nellemann et al., 2003a). Additionally, traffic intensity seems to play a role in the decline of both bird and mammal populations close to roads (Zande et al., 1980; Reijnen et al., 1995; Reijnen et al., 1996; Dyer et al., 1999; Rheindt, 2003; Gagnon et al., 2007).

To quantify the patterns of reduced population densities in relation to infrastructural development, we searched the scientific and non-scientific literature for quantitative data on mammal and bird populations at varying distances from infrastructure. As the metric of effect size, we calculated the ratio between the species abundance at varying distances to infrastructure (Disturbance or Effect distance) relative to the species abundance at the largest (control) distance reported in the study. This ratio is a form of the biodiversity indicator mean species abundance (MSA) which represents the mean abundance of (remaining) original species in an area related to an undisturbed situation (Alkemade et al., 2009). Meta-analysis was used to combine the effect sizes (MSA values) across all studies for several distance intervals and test their level of significance. Furthermore, meta-regression was applied to model the relationship between distance to infrastructure and MSA for birds (MSA_B) and mammals (MSA_M) (infrastructure−distance effect), and to examine sources of heterogeneity in this relationship.

2. Objectives

2.1 Primary objective

The primary objective of the review is to answer the question: “Are mammal and bird populations declining in the proximity of roads and other infrastructure?

2.2. Secondary objectives

By answering the following questions we intend to gain more insight in the relationship between mammal and bird populations and infrastructure, and to examine sources of heterogeneity in this relationship:

- At which distance are mammal and bird populations unaffected by roads and other infrastructure?
- Are mammal and bird populations affected similarly in the proximity of infrastructure?

- Do environmental and geographical factors (e.g. habitat, vegetation cover…) have an effect in the disturbance distances of mammal and birds?
- Does traffic volume affect the abundance of birds in the proximity of roads?

3. Methods

3.1 Question formulation

The Netherlands Environmental Assessment Agency (PBL in Dutch) identified the need for an impartial and independent systematic review to be undertaken to evaluate the impact of infrastructure development on biodiversity. Results of this review would subsequently be implemented in GLOBIO3 model, which is used to estimate the biodiversity loss at global, regional and national level at current state and for possible future scenarios and policy options (Alkemade et al., 2009). The specific questions to be addressed were formulated through discussion between members of PBL, Copernicus Institute (Utrecht University), UNEP-Grid Arendal and Alterra.

The components of the questions of this review are defined in the following table:

Table 1. Definitions of components of the systematic review questions

Subject	Interventions	Comparators	Outcomes			
			Primary	Secondary	Tertiary	Quaternary
Mammal and bird populations affected by road construction and infrastructure development	Proximity to infrastructure (Disturbance distance)	Large distances from infrastructure (Control distance)	Change in abundance of mammal and bird species related to distance to infrastructure	Impact of infrastructure on mammal and bird populations in forested and non-forested areas	Impact of traffic intensity on bird species abundance	Differences in the response of different species populations to infrastructure

3.2 Search strategy

3.2.1. General sources

The following electronic or computerised databases and catalogues were searched:
1. ISI Web of Knowledge (inc. ISI Web of Science and ISI Proceedings)
2. Science Direct
3. Scopus
4. Omega (Utrecht University Digital Library)
5. Ebsco
6. JSTOR
7. Wiley InterScience

8. Springer Link
9. BioOne
10. Picarta
11. CAB Abstracts
12. Encyclopedia of Biodiversity
13. Dissertations Utrecht University
14. Wildlife & Ecology Studies Worldwide
15. Other databases and catalogues deemed relevant by experts

One reviewer searched the electronic or computerised databases and catalogues, and the number of citations retrieved from each search was recorded within an Access database.

An Internet search was also performed using the meta-search engine http://scholar.google.com. The first 50 hits (Word and/or PDF documents where this can be separated) from each data source were examined for appropriate data.

The search strategy covered worldwide literature for the purposes of collecting the broadest scope of information possible. Searches included the following English language search terms (* indicates a wildcard):

1. Road* AND impact* AND biodiversity OR mammals, birds
2. Infrastructure* AND impact* AND biodiversity OR mammals, birds
3. Road* AND distance* AND biodiversity OR mammals, birds
4. Infrastructure* AND distance* AND biodiversity OR mammals, birds
5. Powerline* AND biodiversity* AND mammals, birds
6. Wind park AND biodiversity* AND mammals, birds
7. Infrastructure AND biodiversity* AND mammals, birds
8. Road-effect zone AND mammal abundance OR bird abundance
9. Traffic* AND impact* AND biodiversity OR mammals, birds
10. Traffic volume AND mammal abundance OR bird abundance
11. Road* AND disturbance* AND biodiversity OR mammals, birds
12. Road* AND disturbance* AND mammal abundance OR bird abundance
13. Infrastructure* AND disturbance* AND biodiversity OR mammals, birds
14. Infrastructure* AND disturbance* AND mammal abundance OR bird abundance 15. Road* AND avoidance* AND biodiversity OR mammals, birds
16. Infrastructure* AND avoidance* AND biodiversity OR mammals, birds

3.1.2. Specific key authors

Our previous collective examinations of the literature identified a number of potential key authors (listed below). We searched Scopus and Omega for each of these authors using the author field tag (i.e. to exclude multiple citations).
Cameron, R.D.
Fahrig, L.
Forman, R.T.
McLellan, B.N.
Meunier, F.D.
Nellemann, C.
Reijnen, R.

Shackleton, D.M.
Van der Zande, A.N.
Vistnes, I.

3.1.3 Specialist sources

Bibliographies of articles viewed at full text were searched for relevant secondary articles. Authors and recognised experts in the field of infrastructure development, road establishment and effects on biodiversity (Christian Nellemann, UNEP-Grid Arendal and Rien Reijnen, Alterra) were also contacted for further recommendations, and for provision of any unpublished material or missing data that may be relevant (grey literature). Foreign language searches were undertaken by using cross-reference.

3.3 Study inclusion criteria

One reviewer filtered the most relevant studies by including only those studies whose title and keywords were associated to the objective of this review. Subsequently, all the abstracts from the selected studies were revised and only those satisfying the review criteria were considered. Finally, all the studies selected above were read in full to determine which were suitable for data extraction. A second reviewer checked the studies whose suitability was unclear for the first reviewer. Disagreement regarding inclusion or exclusion of studies was resolved by consensus.

• **Relevant subjects:** Populations of any mammal or bird species. Studies were included irrespective of habitat or spatial scale; however, the biome and/or habitat types were recorded in order to interpret any patterns of variation in the results.
• **Types of intervention**: Disturbance distances or distances close to infrastructure at which mammal and bird populations might be reduced compared to larger distances or control distances (see Types of comparator).
• **Types of comparator:** Control distances or distances at which mammal and bird populations are unaffected by infrastructure and roads.
• Types of outcome: Changes in abundance of mammal and bird populations in the proximity of infrastructure. Differences in the relationships between infrastructure distance and mammal or bird species abundances as a result of vegetation cover. Influence of traffic volume on the response of birds in the proximity of roads. Differences in the relationship between distance to infrastructure and species abundance due to the study of different species populations.
• Types of study: All studies that report on the impacts of infrastructure on mammal and bird populations as long as they present primary data about the relevant subject, such as abundance or density, intervention (varying distances from infrastructure) and comparator (control distance or a distance far enough from infrastructure to be considered as a control distance).
• Potential reasons for heterogeneity: Variation in the response of mammal and birds to different types of infrastructure (highways, secondary roads, oil wells, hydroelectric development, power lines…).
Variation in the type of effect: edge effect, habitat loss, habitat degradation.

Variation between species populations in the response to infrastructure: some of them might be more sensitive to infrastructure than others.

3.4 Study quality assessment

The selected studies to be viewed at full text were considered by one reviewer, excluding them from the review or admitting them to different categories of information quality. Study characteristics were summarized and experimental design (control and treatment plots) and data availability for extraction (means; standard errors and sample sizes) were used as criteria for determining study quality (low; medium-low; medium; medium-high; high) (Table 2). A sensitivity analysis was done by removing studies scoring "medium-low" or "low".Study quality was assessed by one reviewer with reference to a second reviewer in cases of uncertainty. Disagreement regarding study quality was resolved by consensus.

Only papers containing quantitative data on mammal and bird species density or abundance at different distances from linear infrastructure were selected. This implies that each study should report on the abundance or density of birds and /or mammal species at distances close to infrastructure (Disturbance distances) and at distances far from infrastructure or control distances. Studies on the effects of human access, like hunting or tourism, were rejected, in order to limit the systematic review to direct effects of infrastructure.

3.5 Data extraction

No qualitative data was used. Quantitative data was extracted by one reviewer, and a subset of the selected studies was checked by a second reviewer to check data hygiene and verify the robustness and repeatability of the data extraction. The available data was extracted and stored in a database (Access and Excel). The data included density or abundance of each species at different distances from infrastructure, the sample size and the variance, standard deviation or standard error, depending on the study. This data was used to estimate an effect size and its variance needed in the meta-regression (Osenberg *et al.*, 1999). Additional data, for example, on location, habitat, type of effect, taxon and traffic intensity was also recorded. Additionally we stored data on location, habitat, infrastructure type, taxon (order) and traffic volume to explore causes of heterogeneity (Table 2). We think these variables are biologically meaningful and could affect the way species populations respond to infrastructure. We expected that species populations would respond differently to different infrastructure types (lineal and cluster) and in different habitat types (infrastructure visibility is related to vegetation cover), and traffic volume (related to noise and visual stimuli) could play a role in this response.

3.6 Data synthesis

We used the biodiversity indicator mean species abundance (MSA, Box 1), close to infrastructure relative to their abundances at larger, undisturbed distances, as the metric for effect size (Alkemade *et al.*, 2009).

Box 1. Effect-size calculation: Mean Species Abundance

For each study, individual effect sizes were calculated as the ratio between the abundance of each species close to the infrastructure (Disturbance distance) and the abundance of the same species at the largest (control) distance, as reported in the study. Individual effect sizes were aggregated for each study and distance, resulting in an estimate of the mean species abundance (MSA), which is the metric of effect size for the meta-analysis (see eq. 1)

Where MSA_{sd} is the relative mean species abundance estimated in study *s* at a distance *d*; R_{isd} is the ratio between the abundance or density of species *i* at distance *d* and the abundance or density of species *i* at the control distance, calculated as: A_{isd}/A_{isc} for $A_{isc} > 0$. N_s is the number of species considered in study *s*. *MSA* values ranged from 0 to 1 and were decreasing at shorter distances from infrastructure. For species with increasing densities at shorter distances from infrastructure than at the control distance, the *MSA* value was truncated to 1; therefore, if $A_{isd} > A_{isc}$, then $R_{isd} = 1$.

$$MSA_{sd} = \frac{\sum_i R_{isd}}{N_s} \qquad (1)$$

The variance of the MSA value for each distance and study was estimated by calculating the variance based on an external error (2), and on an internal error (3), which are both forms of the variance of a sample mean (Mood et al., 1973). The largest variance was used in the meta-analysis, for taking into account the largest error associated with each data point (DerSimonian and Laird, 1986). For single species' studies, only the variance based on an internal error could be calculated.

The variance based on an external error was calculated as:

$$MSA = \frac{\sum (MSA_{sd} - R_{isd})}{N_s(N_s - 1)} \qquad (2)$$

The variance based on an internal error was calculated as:

$$\sigma^2_{\text{int}} = \frac{\sum \sigma^2_{R_{isd}}}{N_s^2}; \qquad (3)$$

where σ^2_{Risd} is the individual variance for each ratio, which was calculated by using the Delta Method (4), a first-order approximation of the variance of a ratio of two random variables (Oehlert, 1992; Winzer, 2000).

$$\sigma^2_{R_{isd}} = \frac{A_{isd}^2}{A_{isc}^2}\left[\frac{A_{isd}^2}{\sigma^2_{A_{isd}}} + \frac{A_{isc}^2}{\sigma^2_{A_{isc}}} - \frac{2\rho \cdot \sigma_{A_{isd}} \cdot \sigma_{A_{isc}}}{A_{isd} \cdot A_{isc}}\right] \qquad (4)$$

In this equation σ^2_{Aisd} and σ^2_{Aisc} are the variances of A_{isd} and A_{isc}, respectively, and ρ their correlation coefficient. We assume A_{isd} and A_{isc} to be independent and, therefore, the correlation coefficient ρ to be zero. Variances of A_{isd} and A_{isc} were obtained from studies, when available; where this was not the case, the data was assumed to follow a Poisson distribution, in which $\mu = \sigma^2$ and, therefore, $A_{isd} = \sigma^2_{Aisd}$, and $A_{isc} = \sigma^2_{Aisc}$ (Sokal and Rohlf, 1981).

Finally, for studies in which some species had zero densities at disturbance distances ($A_{isd} = 0$), a continuity correction factor (k=1/2) was added to the numerator and denominator of the ratio of each species (also for those with densities larger than zero), resulting in slightly higher variance estimates (Cox, 1970; Sweeting et al., 2004).

3.7 Data analysis

Meta-analyses were performed separately for mammal and bird studies by using the R 2.9.1 software. A random effects meta-analysis was done to derive a pooled effect size for all datasets allowing pseudoreplication. Additionally, meta-analyses were done per distance interval containing non-duplicated independent datasets.

Heterogeneity was assessed by inspection of Forest plots and formal tests of heterogeneity Q and I^2 (Thompson and Sharp 1999). Publication bias was also assessed using Funnel plots of asymmetry along with formal tests (Egger et al, 1997)

To explore factors introducing heterogeneity we built several Generalized Linear
Mixed Models (GLMM), accounting for several alternative nested ecological hypotheses that included the following a priori selected explanatory variables: distance to infrastructure (DIST or LOGDIST when log-transformed), presence of forest cover (FOR), infrastructure type (INFTYP) and traffic intensity (TRAF). Models were compared and selected by means of information theoretic criteria, including Akaike's Information Criterion and Akaike weights. The model selected was that minimising the loss of Kullback-Leibler information.

Additionally data was subgrouped and GLMM were built to examine differences in the relationship between MSA and distance for different habitats, for forested and non-forested habitats (closed and open vegetation), for different infrastructure types (lineal and cluster) and for different taxa.

All GLMM were built in S-Plus 7.0 and fit by restricted penalised quasi-likelihood (Pinheiro and Bates, 2000). Each MSA value was weighed by its variance. Study was introduced as random effect since we expected similar but not identical effect of infrastructure across studies.

4. Results

4.1 Review statistics

More than 600 studies contained relevant titles and abstracts. Of these, 52 studies were selected, but two of them were removed since they reported on species abundance at increasing distances from clearcuts (King et al., 1997) and pastures (Restrepo and Gómez, 1998). Two studies referred to the same data and they were treated as one (Noel et al, 2004; Joly et al, 2006), resulting in 49 studies for the meta-analysis that were published between 1975 and 2008. Some geographical bias was found since most of the studies were from either America (21) or Europe (23), while a few studies from Africa (3) and Oceania (2) were found.

Twenty-seven studies included 201 bird species, and 49 independent datasets were extracted for the meta-analysis. The other twenty-two studies included 33 mammal species, and 41 independent datasets were extracted. Some species were repeated more than once (Appendix 3). From the 49 datasets for birds, 10 contained relevant information on traffic intensities. Of the 41 datasets for mammals, five included information on traffic volumes, which was considered not sufficient for the analysis of the traffic intensity effect (Table 2).

Bird datasets frequently included a large number of species (mean = 9.1 (1-54)), compared to mammal datasets, which (with some exceptions, e.g.: Newmark et al., 1996; Goosem and Marsh, 1997; Yost and Wright, 2001) usually focused on a single species (mean = 3.7 (1-11)). The most represented habitat types within the bird datasets were grasslands and agricultural lands (each of them in 15 datasets), and the least represented was boreal forests (1 dataset) (Table 2). The most represented habitat type in the mammal datasets was arctic tundra (12 times) and the least represented habitat types were grasslands and semi-arid habitats (one time each).

The most represented bird taxon was Passeriformes (21 datasets) and the least represented bird taxa were Coraciiformes, Psittaciformes and Trochiliformes (1 dataset each). The most represented mammal taxon was Artiodactyla (25 datasets) and the least represented mammal taxa were Lagomorpha y Perissodactyla (1 dataset each).

Reported distances within bird datasets ranged from 0-2580 m whereas data points for mammals were obtained within a range of 0-17000 m.

Table 2. Reference, location, habitat, taxon, order, methods, traffic intensity, number of datasets extracted from the study and study quality score of the studies included in the meta-analysis.

Reference	**Location**	**Habitat**	**Taxon**	**Order**	**Methods**	**Traffic intensity**	**Nº datasets**	**Study quality**
Ballasus and Sossinka, 1997	North Rhine Westfalia, Germany	Grasslands & Agricultural lands	Birds	Anseriforme (2 spp)	Dropping densities were counted two times at 4 different feeding sites and at different distance intervals from powerlines. Control distances were 170,170, 210 and 380m. Densities were counted 2 times in 3 parallel transects per study site, except for the first count of the first study site (n=6)		4 (four power-lines)	Medium-High Data on means and SE is provided
Barrios and Rodriguez, 2004	Cadiz Province (Campo de Gibraltar), Spain	Scrublands	Birds	Accipitriforme & Falconiforme (4spp)	Number of raptor birds passing within 250 m of wind turbines were counted in 2 wind parks. The observed distribution of birds at different distance intervals was compared to the expected distribution if they were evenly distributed. Number of birds are given per distance interval. Control distance: 150m		2 (two wind parks)	Medium Total numbers are given. Data calculation and Poisson assumption is needed
Barrows et al., 2006	Coachella valley, California, USA	Desert	Mammals	Rodentia (2spp)	9 treatment plots and 5 control plots were compared. Each plot contained 5-8 100-m transects parallel to roads. Surveys were done in 2003 and 2004. Mean counts and standard errors are reported per distance interval. Control distance: >500m.		1	High Means, SE and sample size are given. Treatment plots and control plots are specified
Bautista et al., 2004	South west Madrid province, Spain	Mediterranean forest	Birds	Accipitriforme & Falconiforme (9 spp)	Raptor observations were recorded near the road (300m) or distant from the road (1000m, taken as control distance) in 10 observation sites. Each site was surveyed for at least 8 days. Mean number of birds per day and square km and SE are given per distance interval and for different traffic intensity (weekdays vs weekends)	5000 cars/day 10000 cars/day	2 (road traffic varies between weekdays and weekends)	Medium-High Data on means and SE is provided. Distance intervals are not clear

Bolger et al., 1997	San Diego county, California, USA	Scrublands	Birds	Passeriforme Trochiliforme Galliforme Columbiforme (20spp)	Point counts were performed on 202 randomly chosen point locations in an undeveloped area close to development. Birds were surveyed and mapped with help of GIS. 9 groups of 20 location points and 1 of 22 were formed. Each group of locations falls in a different distance interval from urbanization and highways. The proportion of points of each group at which the species is detected is plotted again distance. Control distance: 1800m		1	Medium-Low Incidence functions are used. Proportion of locations where species was detected instead of number of individuals is used as measure ofabundance. Data calculation and Poisson assumption is needed
Cameron et al., 1992	Kuparuk Development Area, Alaska, USA	Arctic tundra	Mammals	Artiodactyla (1sp)	Low level aerial surveys were conducted during 10 years in 10 transects. Numbers of caribou were counted within 6km from Milne Point Road. Mean caribou density and SE are given at 1 km distance intervals. Data is split between preconstruction period (1978-81) and postconstruction period (1982-1987). Control distance: 5-6km	150 cars/day	1	High Means, SE and sample size are given. Distance intervals are clear.
Carbaugh et al., 1975	Allegheny Plateau, Pennsylvania, USA	Temperate deciduous forest and Agricultural lands	Mammals	Artiodactyla (1sp)	The highway at two study sites was divided in contiguous 61m-long sectors. Data on numbers of deer, approximate distance of deer to highway, and behavior of deer were taken from a vehicle driven on the emergency lane. 216 and 189 runs were done at each study site. Numbers of deer seen on the highway (0-1m), right-of-way (1-60m), the agricultural fields (60-300m) and the woods (>300m) are given. Control distance: 180 m and 350m		2 (two habitat types)	Medium-Low Total numbers are given. Data calculation and Poisson assumption are needed. Distances are not clearly specified.
Clark and Karr, 1979	Central Illinois, USA	Agricultural land	Birds	Passeriforme (2spp)	Bird censuses along county roads (n= 18 transects; 86 counts) and interstate highways (n= 15		2 (county roads and	Medium

					transects; 69 counts) were conducted in late winter-early spring and late spring. Mean number of birds per distance interval are given for both study sites and periods. Data for different periods was pooled. Control distance: 450m		interstate highways)	Mean densities are given together with sample size.
Cronin et al., 1998	Prudhoe bay, Alaska, USA	Tundra	Mammals	Artiodactyla (1sp)	Numbers of caribou and locations were recorded during 37 aerial surveys along 29 width fixed transects. Observations were recorded during 1990-1995 and grouped in 1km distance intervals from oil field structure. Control distance: 11-23km (17km was used)		1	Medium-High Total numbers per year and distance interval are given. Data calculations were needed.
Delgado et al., 2004	Tenerife Island Spain	Tropical forest	Birds	Passeriforme Columbiforme (8spp)	Breeding birds were censused in 0.5ha subplots located at the edge of the road (n=339 or in the interior of the forest (n=216). 3 replicates per census unit. Control distance: 50m (interior)	1229 cars/day	1	Medium-High Mean, SD and sample size are given. Distances are not clearly specified, but treatment plots and control plots are clear. Census methodology is not elaborated in the study
Develey and Stouffer, 2001	Central Amazonia, Brazil	Tropical forest	Birds	Passeriforme (9spp)	Treatments (road plots) are compared to control (interior plot; 400 m from road), each of them with 5 replicates. Species flocks were followed systematically, and their location and species composition were recorded at 30-minute interval. Frequency of core bird species within the flocks was measured (n=444 observations). Control distance: 400m	10 cars/week	1	Medium-High Mean frequency, SD and sample size are given. Distances for road plots are not totally clear.

Devereux et al., 2008	East Anglia, United Kingdom	Agricultural lands	Birds	Passeriforme Galliforme Anseriforme Columbiforme Falconiforme Charadriiforme (23spp)	Bird survey data were collected from farmland immediately surrounding two operational wind farms in winter 2007. Bird observations were grouped in distance intervals from wind turbines. Surveys were repeated 11 times along fixed line transects. Results are presented for both wind farms using site as random effect. Control distance: 600–750 m.		1	Medium Total counts and total number of visits are given. Data was recalculated and Poisson assumption was used. Distances are clear.
Dyer et al., 2001	North-East Alberta, Canada	Boreal forest	Mammals	Artiodactyla (1sp)	23 woodland caribou were captured and fitted with GPS-collars. Buffer zones were generated with GIS at different distances from roads, seismic lines and well sites. Avoidance was measured as the proportional use (nº of locations) of buffer zones by caribou compared to expected use. Control distance: 3500 m (roads); 750m (seismic lines); 1500m (well sites)	400 cars/day	3 (roads, seismic lines and oil well sites)	Medium Measure of abundance is proportion of locations instead of densities or counts. SE and sample size are given. Distances are clearly reported
Gill et al., 1996	Scolt Head Island, north Norfolk, United Kingdom	Agricultural fields	Birds	Anseriforme (1sp)	The number of geese was recorded daily (between October 1992 and February 1993) on 15fields. All these summed give the total number of goose-days on the field. Total number of goose-days per ha was highly related with the distance from the flock at first landing to the nearest road. So geese tend to land on fields farther from roads. Control distance: 700m		1	Medium-Low Total number of goose-days per ha are given. Poisson assumption is needed. Methodology is not well explained. Replicates are missing or not clearly reported.
Goosem and	North-East	Tropical forest	Mammals	Rodentia	Rodents were trapped at different distances from a		1 (data	High

Marsh, 1997	Queensland, Australia			(3spp)	powerline corridor in 4 sites (2 regrowth sites, and grassy sites). Mean capture rate is used as measure of abundance. Only grassy sites were used for meta-analysis since in regrowth corridors the rainforest created a continuous canopy connection and no real clearing existed. Control distance:110m		from grassy sites was pooled)	Mean, SE and sample size are reported. Distances are clear.
Hüppop and Hüppop, 1995	Schleswig-Holstein (Nordstrandischmoor island), Germany	Saltmarshes	Birds	Charadriiforme (4spp)	1485 nests of coastal birds were mapped on a saltmarsh island in 1993. Frequency of nests is plotted at different distances from the only road that runs through the island. Control distance: 225m		1	Medium-low Methodology is poorly reported. Data calculation was needed. Distances were grouped in intervals of similar length and means and SD were calculated. Distances are clear.
Keller, 1991	Newburg, Grampian, United Kingdom	Agricultural land	Birds	Anseriforme (2spp)	Flocks were located by searching the study area from Sept. 88-January 89. Flocks were mapped and distances to the road were measured. The distribution of these distances was compared with that of randomly selected points that also fell within the feeding area. (n=115). Control distance: 565m	4200 cars/day	1	Medium-low No means or SE. No replicates. Distances are clear but no control plots and/or treatment plots are defined.
Kroodsma, 1984	Eastern Tennessee, USA	Temperate deciduous forest	Birds	Passeriforme Cuculiforme Piciforme (19spp)	Four breeding bird censuses were conducted with the territory-mapping method in two rectangular forested plots adjacent to power-line corridors. Plots were divided in strip transects parallel to the corridor. The first strip transect for each plot was adjacent to the power-line corridor, and the		1	Medium Mean densities and sample sizes are reported.

					remaining transects were successively deeper into the forest. Density data was pooled over the 4 years. Control distance: 500m			Distances are clear. Methodology is clear and treatment plots (edge) and control plots as well (interior)
Kuitunen et al., 1998	Central Finland	Boreal forest	Birds	Passeriforme Apodiforme Columbiforme Cuculiforme Piciforme Galliforme Charadriiforme (54spp)	Birds were censused by line transect method. Two transects of 0.7–1.3 km were placed at 17 roadside locations parallel to highways. The first transect was situated 25 m from the outer edge of the road ditch and the other transect was situated 200 m away from the first one. Control distance: 225m	7000 cars/day	1	Medium-High Mean densities and sample size are given. Poisson assumption is used. There are clear treatment and control plots.
Lane et al., 2001	South and East of Madrid Province, Spain	Agricultural areas	Birds	Gruiforme (1sp)	Seven censuses were conducted between 1997 and 1999 by driving predetermined transects. Flocks were plotted on maps and distances to nearest urbanized area, road, building, electric cable or track were measured. Flock positions were pooled from all censuses (n=619)and compared to representative points falling within site boundaries (n= 419) Control distances: 1720m (road), 900m (electric line), 240m (tracks), 2580m (urban areas), 1175m (buildings).		5 (1 per infrastructure type)	Medium-Low No means or SE. Frequency distributions are shown. No clear comparators.
Larsen and Madsen, 2000	Northwest Jutland, Denmark	Grasslands	Birds	Anseriforme (1spp)	2–3 perpendicular transects were laid out at intervals of about 200 m from powerlines and two wind parks. Along each transect droppings were counted in plots of 1 m radius (3.14 m2) at intervals of 25 m. Control distance: 200m (powerlines), 300m (cluster of wind turbines), 200m (line of wind turbines)		3 (three study sites and 2 infrastructure types)	Medium-High Means and sample sizes are given. Poisson assumption is used.

Laurance et al., 2006	Rabi region, Gabon	Tropical forest	Mammals	Artiodactyla Proboscidea (2spp)	6 study sites were chosen with 5 parallel transects to the road. Standardized estimates of species abundances were calculated by reporting the numbers of 50-m segments on each 1-km transect in which a species or its sign was detected. This yielded a 0–20 score for each species. Data from four censuses were pooled to yield an average value on each transect for each species. Control distance: 1200m		1	Medium-High Sample sizes and raw data is given so that means and SD are easily calculated. Experimental design clear.
Madsen,1985	West Jutland, Denmark	Extensive grassland and Agricultural land	Birds	Anseriforme (1sp)	Filso area: Goose counts and mapping of flocks at regular intervals were to estimate abundance (mean nº goose per ha and visit). Data of agricultural fields at similar distance from roads were grouped. Control distance: 650m Tipper peninsula: Density of droppings was assessed in 20 m^2 circles with 40 m intervals along transects perpendicular to roads (n= 4 dropping samples per interval). Control distance: 320m	Between 1 car/day and 30 cars/day	2 (2 habitat types)	Medium-Low Filso: Mean is given for but sample size and SD are unclear. Poisson assumption used. Data from two roads is pooled. Tipper: Data is given as % of maximum utilization. Sample size is clear. Data from two roads is pooled for calculating variances.
Mahoney and Schaefer, 2002	Newfoundland, Canada	Tundra	Mammals	Artiodactyla (1sp)	54 caribou individuals were radiotracked for at least 360 days and 30 locations (1995-1999) Changes in the distribution of animals surrounding hydorelectric development were determined by computing the proportion of all radio-tracked individuals in each year with at least one location at 0–3, 3–6, 6–9, and 9–12 km from the site. Control distance: 10500m		1	High Means and SE are given for preconstruction and postconstruction periods.

								Distances are clear.
Malcolm and Ray, 2000	South-West of Central African Republic	Tropical forest	Mammals	Rodentia (12spp)	280-m long transects were laid in 2 logged (12 years-old and 19 years-old) and 1 unlogged forest (control). In each logged forest 3 transects were devoted for each type of road: primary, secondary and skid trails. Each transect was surveyed once using small-mammal-live traps located at 2-15m from forest edge. Mean capture rates are used as abundance estimate. Control distance: >2km		6 (six different sites with different environmental conditions)	Medium-High Means, sample sizes and SE are given. Treatment and control plots are clear.
McLellan and Shackleton, 1989	Flathead river, British Columbia (Canada) and Montana(USA)	Boreal Coniferous Forest	Mammals	Carnivora (1sp)	Comparison of radio-locations of the same grizzly bears, recorded before, during, and after industrial activity (seismic lines) and in three different buffer zones from seismic lines (0-500m, 500-2000m, >2000m). Radio-collared bears were relocated from fixed-wing aircraft approximately once each week, while ground tracking along the road network was more frequent. Control distance: >2km		2 (during and after operations)	Medium-High Raw data per bear is given allowing data calculation (means and SE). Treatment and control plots are clear.
Meunier et al., 1999	North-East of Nimes, South-East of Bordeaux and South of Niort; France	Scrublands, temperate mixed forest and agricultural lands	Birds	Passerifome Galliforme Accipitriforme Columbiforme Falconiforme Apodiforme (38 spp in scrublands,43 spp in temperate forest, and 38spp in agricultural lands)	Transect counts were used to record birds present in roadsides (n=3) and adjacent habitats (n=3) in three contrasting environments. Each transect was surveyed several times (3 in autumn and winter and 5 in spring and summer). Control distance: 250m	25000 cars/day 52000 cars/day	3 (3 different study sites and habitat types)	Medium Nº of presences is given per plot is given. No SE. Sample size is given. Poisson assumption is used. Treatment and control plots are clear.
Meunier et al., 2000	South of Niort, France	Agricultural lands	Birds	Accipitriforme Falconiforme	Data were collected using the road transect method in secondary roads and motorways (33km in each road; n= 42 surveys). Raptors were counted when seen in two zones from the road: 0±50 m (zone 1), 50±100 m (zone 2).	1000 cars/day 25000 cars/day	2 (highways and secondary roads)	High Means, SE and sample sizes are given.

					Control distance: 75m			Treatment and control plots are clear.
Nellemann and Cameron, 1996	Prudhoe Bay, Alaska, USA	Tundra	Mammals	Artiodactyla (1sp)	Low-level aerial surveys were conducted along 16 40-60 km-long transects between 1987-1991.Each caribou group was located and mapped. Caribou densities were calculated for different distances from oil field development area (0-4; 4-10 and >10km). Control distance >10km		2 (flat and rugged terrain)	High Means, sample sizes and SE are given. Control and treatment distances are clear.
Nellemann et al., 2001	Nordfjella Mountain Region, Norway	Tundra	Mammals	Artiodactyla (1sp)	Systematic aerial surveys of the distribution of ca. 2500 reindeer were conducted during late winter 1986–1998. Mean density was calculated for three 2.5 km intervals from power lines without adjacent roads or cabins (0.0–2.5; 2.6–5.0; and >5.0 km). Control distance: >5km		1	High Means, sample sizes and SE are given. Control and treatment distances are clear
Nellemann et al., 2003	Setesdal-Ryfylke, southwestern Norway	Tundra	Mammals	Artiodactyla (1sp)	Monthly surveys of >2000 reindeer (Rangifer tarandus tarandus) were done from 1977 to 1987 before and after the construction of the Blue Lake hydroelectric reservoir. Surveys were done in 54 5x5km sites, which were categorized as developed by powerlines in 1965 (n=11), developed by power lines and gravel roads in 1980–1987(n=21), and controls (n=23) that remained undeveloped throughout the entire sampling period. Control distance: >4km		2 (during and after developmen t)	High Means, sample sizes and SE are given. Control and treatment distances are clear
Newmark et al., 1996	Mikumi National Park, Tanzania	Grasslands	Mammals	Artiodactyla Perissodactyla Proboscidea (5spp)	Distribution of mammals in relation to a highway was estimated through ground surveys using a strip transect method (n=151). Observed frequency of sightings is compared to expected frequency for a vegetation type.. 3 species are combined due to small sample size. Control distance: 4km		1	Medium Frequency of sightings instead of means. No SE. Sample size is reported. Poisson

								assumption is used. Control distances are not specified.
Noel et al., 2004 and Joly et al., 2006	Milne point area, Alaska, USA	Tundra	Mammals	Artiodactyla (1sp)	Joly et al (2006) reanalyzed the data from Noel et al (2004), to prove that, contrary to Noel et al.,´s conclusions, caribou distribution was affected by oil development on Alaska's North Slope. Data was collected by aerial surveys for the period 1991-2001 and from Dau and Cameron (1986) and Cameron et al (1992) for the period 1978-1987. Control distance: 5500m		2 (during and after developmen t)	Medium-High Raw data from Noel et al (2004) was used to obtain means and SE. Control distance was the largest reported
Oehler and Litvaitis, 1996	New Hampshire, USA	Temperate mixed deciduous forest	Mammals	Carnivora (2spp)	No of wild canid tracks were counted in three different landscapes with increasing levels of fragmentation due to urban development. Each landscape consisted of 3 plots where transects were followed for counting tracks. This was repeated twice. Observed and expected distributions of tracks are presented at different distance intervals from urban development. Control distance: 150m		3 (study areas)	Medium-low Sample size is given. No SE. No clear control distance. The largest distance reported in the paper is used as control. Data for the two species are grouped.
Ortega and Capen, 1999	Green Mountain National Forest, Vermont, USA	Temperate deciduous forest	Birds	Passeriforme (1sp)	7 plots were established adjacent to forest roads. Plots were divided into edge areas (<150m from roads) and interior areas (150-300m from roads). Male territories were located using the spot-mapping technique in 10 censuses per plot. Control distance: 275m		1	High Means, SE and sample sizes are given. Control and treatment plots are clear
Paruk, 1987	Mississippi river, Illinois, USA	Temperate forest	Birds	Accipitriforme (1sp)	An aerial bald eagle survey was performed over three sections of river Mississippi by flying over 2 census routes (12 times). Censuses were repeated 12 times. 4 heavy, 6 moderate and 11 light bald eagle use areas were identified and used for the analysis. Distance of eagles to roads was measured		1	Medium-low Raw data is given. Data calculation was needed. Control

					for heavy and light use areas. Control distance: 1.5km			distances are not clear
Piper and Catterall, 2006	Brisbane region, Australia	Subtropical forest	Birds	Passeriforme Psittaciforme Accipitriforme (25spp)	8 transects close to roads (>100m) were compared with 8 matched control transects within forest about 150m away from road transects. Four 20 min counts were carried out within each transect and all bird species seen or heard within were recorded and their number estimated. Average number of birds across 4 visits was used for analyses. Control distance: 300m		1	Medium Sample size is given. Number of sites with a species present is given instead of abundance. Control and treatment plots are clear
Reijnen and Foppen,1994	South of Utrecht, The Netherlands	Grasslands and scrublands	Birds	Passeriforme (1sp)	The area for each habitat type was divided into three zones: a 'road zone' (0- 200 m from the road), an 'intermediate zone' (200 - 400 m) and a 'control zone' (> 400m from the road). Territorial males were mapped six times or more from April until June (1989-1991). The density was calculated as the number of territories per ha (averaged for the three years). Control distance: > 400m	50000 cars/day	2 (2 habitat types)	High Mean, SE and sample size are given. Control and treatment plots are clear.
Reijnen et al., 1995	Several areas scattered over The Netherlands	Temperate deciduous and coniferous forest	Birds	Accipitriforme Anseriforme Charadriiforme Columbiforme Cuculiforme Galliforme Passeriforme (41 spp in deciduous forest & 18spp in coniferous forest)	Paired plots were selected in deciduous forest (n= 38) and coniferous plots (n= 17). Each paired plot consisted of a road plot and a control plot (> 400m from road). Breeding bird densities were measured using the mapping method. Control distance: >400m	30334 cars/day 45319 cars/day	2 (2 highways with different traffic intensities)	Medium-high Mean and sample size are given. Control and treatment plots are clear.
Reijnen et al.,1996	North and west of the Netherlands	Grasslands	Birds	Anseriforme Charadriiforme Gruiforme Passeriforme (12spp)	15 transects perpendicular to roads were established. Transects started at the roadside and were 634-2626m long. Transects were divided in 20-25 ha strips. Breeding bird densities were measured from individual registrations of territorial	5000 cars/day 50000 cars/day	2(2 different traffic intensities)	Medium-low Means are not given, only percentage of

					behavior made in several visits. Traffic noise was also measured. Percentage of population loss due to noise disturbance is calculated with a model at different distances from road (100; 500; 1500m). No control distance.			population loss at different distance from road, which is used as individual ratio for meta-analysis. MSA values per distance are calculated aggregating these ratios. Variances of the external error are calculated. Individual species variances (needed for comparison between taxa in meta-regression) were assigned by using the largest variance calculated for that species in another study.
Rheindt, 2003	Würzburg, Bavaria, Germany	Temperate deciduous forests	Birds	Passeriforme Piciforme (15spp)	Breeding birds were surveyed in a 1225 m transect parallel to a motorway at a distance 100 m throughout the breeding season in 1999. A control transect (1225m) at 950m from the motorway was surveyed during the same period. 7 census walks were done. Traffic noise was measured. Control distance: 1000m	50000 cars/day	1	Medium Mean densities or SE are not given. Impact is measured as change in abundance of each individual species from

								control to road transect. MSA values per distance are calculated aggregating these ratios. Variances of the external error are calculated. Individual species variances (needed for comparison between taxa in meta-regression) were assigned by using the largest variance calculated for that species in another study.
Rich et al., 1994	Southern New Jersey, USA	Temperate deciduous forest	Birds	Passeriforme (1sp)	Fixed-radius (100-meter) point counts were conducted on 54 transects established along three width classes of corridors: unpaved roads (8 meters wide), paved roads (I6 meters wide), and powerlines (23 meters wide). Transect locations were distributed equally among corridor edge, forest margin 100 m from corridor edge, and forest interior 300 m from corridor edge. Control distance: 300m		3 (3 infrastructure types)	High Mean, sample size and SE are given. Control and treatment plots are clear.
Roedenbeck et al., 2008	Canton Aargau in Northern Switzerland	Agricultural areas	Mammals	Lagomorpha (1sp)	Hare population abundances were obtained from spotlight taxations conducted by huntsmen in the years 2003 and 2005. 111 longitudinal plots (500×100 m) parallel to road segments were established. Plots were classified in 5 distance classes and number of hares per plot was	140000 cars/day	1	High Mean, sample size and SE are given. Control distance is

					calculated. Control distance: 550m			assumed to be the largest distance interval.
Rost and Bailey, 1979	North and Central Colorado, USA	Boreal forest and scrublands	Mammals	Artiodactyla (2spp)	Deer and elk (Cervus canadensis) distributions in relation to roads were assessed by counting fecal-pellet groups near roads in shrub, pine and juniper woodland habitats east and west of the continental divide (n= 12 per study area). Control distance: 350m		4 (2 study areas with 2 habitat types each)	Medium Mean and sample size are given. Control distance is assumed to be the largest distance interval. Poisson assumption is used to estimate the variance.
Tigas et al., 2002	Simi hills and Conejo valley, South California, USA	Chaparral (Scrublands)	Mammals	Carnivora (2spp)	Bobcats and coyotes were captured and collared.13 bobcats and 9 coyotes were relocated. 53 focal sessions were used and bobcat and coyote locations were classified as fragment interior (>100 m from development), edge (<100 m from development) or development. Control distance: >100m		1	Medium Proportion of locations is given instead of number. Sample size is given. Treatment and control distances are clear.
Van der Zande et al., 1980	Zuid-Holland province, The Netherlands	Agricultural lands	Birds	Charadriiforme (3spp)	The four study areas (polders) were visited several times (n=11; n=9;n=5; n= 1) and intensively surveyed. Birds territories were mapped and number of encounters was also used as abundance estimate. Transects were established perpendicular to the roads, divided into a number of strips with equal area. For each strip both the number of encounters and the number of territories were counted. Control distance: 2000m; 750m;1125m;1060m	54000 cars/day 7311 cars/day 4560 cars/day 50 cars/day	4 (4 study sites with different traffic volumes)	Medium Mean and sample sizes are given. Distance intervals are clear. Disturbance distance at which maximum density is

								reached is the control distance interval.
Van der Zande et al., 1980 (after Veen, 1973)	Eilandspolder, The Netherlands	Grasslands	Birds	Charadriiforme (4spp)	Van der Zande et al. (1980) reanalyzed data from another study (Veen, 1973) on the abundance of nests of 4 species in relation to roads (n=2) for the years 1968, 1970 and 1971. Control distance: 1800m		1	Medium Total numbers are given for two transects. Means and variances are calculated from these data. The control distance is the largest distance interval.
Van Dyke and Klein, 1996	Line Creek Plateau, Montana, USA	Boreal forest	Mammals	Artiodactyla (1sp)	Seasonal and annual use of range and habitat in the population of elk during the period 1988-1991 were compared before, during, and after installation of an oil well. Elk locations in 1km-cells adjacent to oil well are compared to elk locations far from oil well for four seasons. Control distance: > 1000m	25 cars/day	1	Medium Number of locations is aggregated for four seasons and mean and variance is calculated. Treatment and control distances are not clear.
Vistnes and Nellemann, 2001	Repparfjord Valley, North of Norway	Tundra	Mammals	Artiodactyla (1sp)	The distribution of reindeer was mapped during the 1998 and 1999 calving seasons (n=776 and n= 668) using systematic snowmobile and ski surveys. The study area was divided in quadrats and for each quadrat the mean density of observed reindeer was calculated across years (1998-1999). Control distance: > 4000m		1	High Mean, SE and sample size are given. Control and treatment distance intervals are clear.

Yost and Wright, 2001	Denali National Park, Alaska, USA	Tundra	Mammals	Artiodactyla Carnivora (3spp)	Data were collected from 22 samplings of 19viewsheds along a road corridor in 1996 and 1997. 9 backcountry viewsheds (control) were established in three different areas to determine whether density estimates for each species in the backcountry were higher than those for the same animals in similar road-corridor areas. Observed and expected densities are compared. Control distance: 1050m	150 cars/day	1	Medium-High Number of groups and sample size are given. Poisson assumption is used to estimate variance. Control and road distance intervals are clear

4.2. Results of the meta-analysis

4.2.1. Combination of all distances with pseudorreplication

The pooled effect size derived from an all-encompassing meta-analysis of MSA values for birds indicated that bird abundance declined within ca. 2600 m from infrastructure (MSA_B = 0.678; 95% C.I. 0.636 to 0.720, P< 0.0001; Table 3). Likewise for mammals, MSA_M decreased within 17000 m from infrastructure (MSA_M = 0.675; 95% C.I. 0.608 to 0.742, P< 0.0001). However, for both meta-analyses there was large heterogeneity and publication bias within the datasets (Q_B=16938.28, P< 0.0001; Egger $test_B$ = 5.785, P< 0.0001; Q_M=3466.80, P<0.0001; Egger $test_M$= 3.684, P<0.0001; Tables 3 and 4). Failsafe numbers indicated that a considerably large number of studies reporting neutral or positive effects of the proximity of infrastructure on species abundance would be needed to overturn these results and so even with some publication bias, the results for mammals and birds can be considered a reliable estimate of the true effect (Rosenthal et al., 1979).

Sensitivity analyses were performed and the results remained similar after removing studies that scored “medium-low” in the study quality assessment. The pooled effect size for bird data increased slightly, heterogeneity was lower but still statistically significant and there existed publication bias (MSA_B = 0.683; 95% C.I. 0.627 to 0.740, P< 0.0001; Q=2653.70, P< 0.0001; Egger test = 4.699, P< 0.0001; Appendix 4). For mammals the pooled effect size was similar, heterogeneity decreased slightly and publication bias also continued to exist (MSA_M = 0.678; 95% C.I. 0.6086 to 0.7472, P< 0.0001; Q=3401.70, P<0.0001; Egger test = 4.006, P<0.0001; Appendix 4).

4.2.2. Effect size per distance interval

Pooled effect sizes calculated per distance interval for independent datasets were significant for mammal and bird data, but considerable heterogeneity and publication bias existed for most of the intervals. Lower MSA values were obtained at shorter distance intervals to infrastructure for both mammals and birds. The number of datasets per distance interval decreased as the distance from infrastructure increased (Table 3 and 4).

Sensitivity analyses for mammal and bird data resulted in similar MSA values per distance interval with the exception of the distance intervals 300-320, 340-375 and 380-490 m for the bird data, which had larger MSA values (Appendix 4). Heterogeneity was not statistically significant in these intervals, but there existed publication bias.

Table 3. Meta-analysis for bird species at different distance intervals.

Distance (m)	n	Effect size (MSA)	SE	CI.(lb)	CI.(ub)	P(e.size)	Q	P(Q)	I^2 (%)	Egger´s test intercept	P(t) Egger	Fail-safe N
0-2580(alldist.)	288[2]	0.6777	0.0215	0.6355	0.7200	**<0.0001**	16938.28	**<0.0001**	96.6	5.785	**<0.0001**	**1123452**
<10	10	0.3983	0.1290	0.1455	0.6512	**0.002**	62.7322	**<0.0001**	94.4	2.625	**0.0026**	**245**
15-35	18	0.4855	0.0893	0.3105	0.6605	**<0.0001**	223.89	**<0.0001**	93.3	4.336	**<0.0001**	**2233**
38-65	20	0.5339	0.0905	0.3566	0.7112	**<0.0001**	370.28	**<0.0001**	95.2	3.639	**<0.0001**	**1939**
70-80	16	0.5923	0.0896	0.4165	0.7680	**<0.0001**	33.19	**0.007**	54.5	2.561	**0.0002**	**689**
90-100	16	0.6218	0.0722	0.4802	0.7634	**<0.0001**	38.42	**0.0004**	68.4	3.993	**0.0003**	**1494**
110-125	13	0.6673	0.1022	0.4671	0.8676	**<0.0001**	40.99	**<0.0001**	65.7	3.072	**0.0001**	**577**
130-140	5	0.7070	0.1592	0.3950	1.0190	**<0.0001**	45.79	**<0.0001**	85	4.981	**0.0222**	**225**
150-160	16	0.5978	0.0788	0.4434	0.7522	**<0.0001**	79.12	**<0.0001**	83.8	4.874	**0.0002**	**1946**
170-180	10	Fisher scoring algorithm did not converge										
190-200	13	0.6292	0.0908	0.4512	0.8072	**<0.0001**	301.50	**<0.0001**	95.7	6.786	**0.0015**	**2864**
210-240	12	0.6734	0.1281	0.4223	0.9246	**<0.0001**	428.83	**<0.0001**	95.3	5.434	**0.0124**	**1560**
250-280	17	0.6676	0.0963	0.4789	0.8563	**<0.0001**	331.47	**<0.0001**	96.5	9.347	**0.0122**	**9320**
300-320	15	0.7454	0.1062	0.5374	0.9535	**<0.0001**	8769.78	**<0.0001**	99.4	15.540	0.202	**20053**
340-375	10	0.6432	0.0943	0.4583	0.8281	**<0.0001**	34.74	**0.0001**	75.2	4.828	**0.0161**	**851**
380-480	16	0.7495	0.0888	0.5755	0.9236	**<0.0001**	1052.78	**<0.0001**	96.9	8.952	**0.0003**	**7820**
490-550	14	0.6946	0.1004	0.4978	0.8914	**<0.0001**	86.19	**<0.0001**	87	5.331	**0.0073**	**2013**
565-645	9	0.7182	0.0929	0.5361	0.9003	**<0.0001**	27.72	**0.0005**	75.8	6.594	**0.0436**	**1294**
650-785	11	0.7564	0.1203	0.5206	0.9921	**<0.0001**	581.18	**<0.0001**	94.1	5.980	**0.0451**	**1588**
800-860	3	0.6869	0.1968	0.3011	1.0728	**<0.0001**	12.75	**<0.0001**	81.1	4.640	**0.0124**	**69**
900-915	4	0.9152	0.1043	0.7108	1.1196	**<0.0001**	0.2687	0.9658	0	4.1168	**0.0189**	**97**
1000-1075	11	0.8363	0.0791	0.6812	0.9913	**<0.0001**	17.23	0.0695	46.7	4.585	**0.0050**	**930**
1100-1175	3	0.9696	0.1275	0.7198	1.2195	**<0.0001**	0.0722	0.9645	0	4.052	0.0780	**52**
1200-1290	4	0.8308	0.1097	0.6158	1.0459	**<0.0001**	5.011	0.171	47	5.426	**0.0344**	**171**
1300	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1400	2	0.9098	0.0515	0.8090	1.0107	**<0.0001**	0.0398	0.842	0	10.941	0.321	**176**
1500-1505	7	0.8511	0.0677	0.7183	0.9838	**<0.0001**	13.894	**0.0308**	71.7	10.572	0.0516	**2018**
1600	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1700-1750	4	0.9294	0.0992	0.7349	1.1239	**<0.0001**	0.5252	0.9133	0	4.4439	**0.0148**	113
1800-2000	4	1.0000	0.0483	0.9053	1.0947	**0.0000**	0	1.0000	0	7.868	0.136	362
2150	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2365	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2580	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

[2] Total number of MSA values included in the meta-analysis for bird species. The total number of studies is 27, from which 49 datasets were extracted containing 288 MSA calculated values for different distances.

Table 4. Results of the meta-analysis for mammal species at different distance intervals

Distance(m)	n	Effect size (MSA)	SE	CI.(lb)	CI.(ub)	P(e.size)	Q	P(Q)	I^2 (%)	Egger´s test intercept	P(t) Egger	Fail-safe N
0-17000	151[3]	0.6746	0.0342	0.6076	0.7415	**<0.0001**	3466.80	**<0.0001**	90.7	3.6843	**<0.0001**	**114151**
1	6	0.1528	0.1005	-0.0442	0.3498	>0.1	12.74	**0.0259**	71.9	1.0862	0.0937	10
10-25	11	0.7110	0.0451	0.6227	0.7993	**<0.0001**	4.38	0.9284	0	4.300	**<0.0001**	**816**
30-50	16	0.5651	0.0726	0.4229	0.7073	**<0.0001**	28.65	0.0178	55.8	2.9972	**<0.0001**	**834**
75-100	7	0.3957	0.1831	0.0369	0.7545	**<0.05**	10.87	0.0925	47.7	1.4193	**0.0016**	**362**
110-180	16	0.8374	0.0520	0.7354	0.9394	**<0.0001**	7.42	0.9448	0	3.4069	**<0.0001**	**1083**
200	2	0.6104	0.2382	0.1435	1.0774	**0.0104**	0.02	0.878	0	1.464	0.402	2
250-300	9	0.8470	0.0627	0.7241	0.9698	**<0.0001**	7.78	0.4557	7.8	4.059	**0.0037**	**485**
350-600	19	0.6222	0.1115	0.4035	0.8408	**<0.0001**	206.68	**<0.0001**	91.9	3.3561	**<0.0001**	**1485**
750-1000	6	0.8669	0.1052	0.6608	1.0731	**<0.0001**	9.23	0.1002	50.2	4.8430	**0.0036**	**307**
1050-2200	20	0.5786	0.0806	0.4207	0.7366	**<0.0001**	75.49	**<0.0001**	74.1	3.0049	**<0.0001**	**1316**
2500	8	0.8233	0.2098	0.4121	1.2345	**<0.0001**	0.9453	0.9957	0	1.2516	**0.0020**	30
3500-4000	7	0.9807	0.1276	0.7307	1.2308	**<0.0001**	0.2907	0.9995	0	1.9095	0.0775	**60**
4500-5000	8	0.8666	0.1099	0.6512	1.0820	**<0.0001**	6.06	0.5323	30.8	3.395	**0.0255**	**265**
5500-7000	8	0.8049	0.1983	0.4163	1.1936	**<0.0001**	0.8083	0.9974	0	1.2467	**0.0039**	29
7500	2	0.8730	0.0118	0.8498	0.8962	**<0.0001**	0.0084	0.9272	0	37.35	0.494	**2047**
8500	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
9500-11000	4	1.0000	0.0131	0.9744	1.0256	**<0.0001**	0	1	0	76.122	**<0.0001**	**2527**
17000	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

[3] Total number of observations points or MSA values included in the meta-analysis for mammal species. The total number of studies is 22, from which 41 datasets were extracted containing 151 MSA calculated values for different distances.

4.2.3. Exploration of reasons for heterogeneity: Meta-regression

The relationship between MSA and distance to infrastructure was positive for both mammals and birds (Fig. 1 and 2). When the data was subgrouped per habitat, all relationships were also positive except for temperate forests in the case of mammal species, and Mediterranean forests in the case of bird species (Tables 6 and 7). In forests both bird and mammal species abundances were affected in the proximity of infrastructure whereas in non-forested areas the effect extended over a larger distance (Table 8). All relationships had lower AICc when "LOGDIST" was chosen as explanatory variable, except for Tundra.

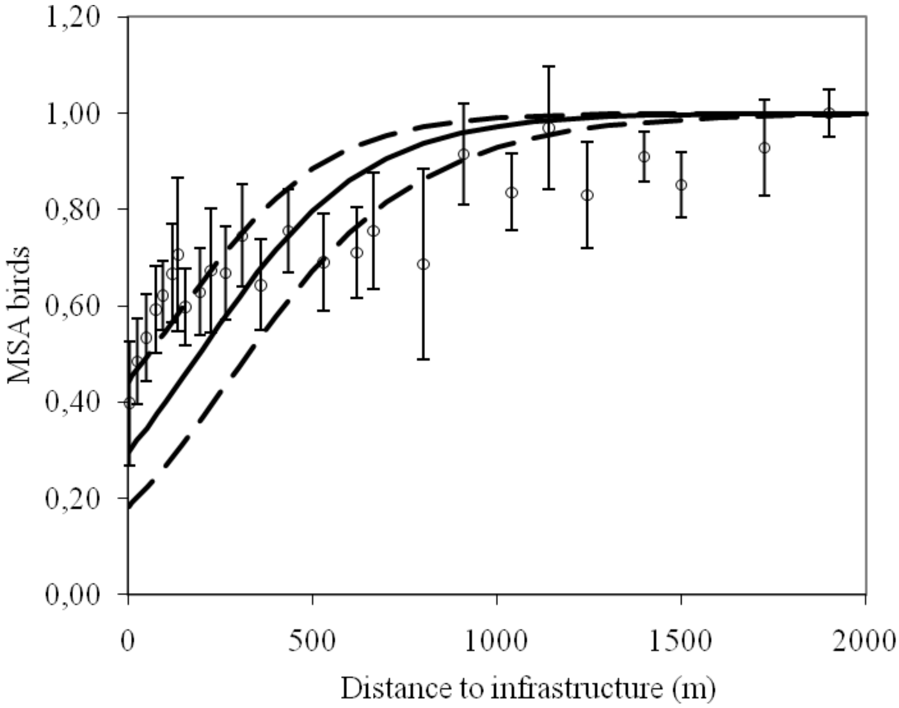


Figure 1. Logistic regression between mean species abundance of birds and distance from infrastructure. Open dots represent the pooled results of the meta-analysis per distance interval ± S.E. The black line denotes the estimated curve for the decline of MSA, related to distance. Dashed lines are the 95% upper and lower limits of the confidence bands of the curve.

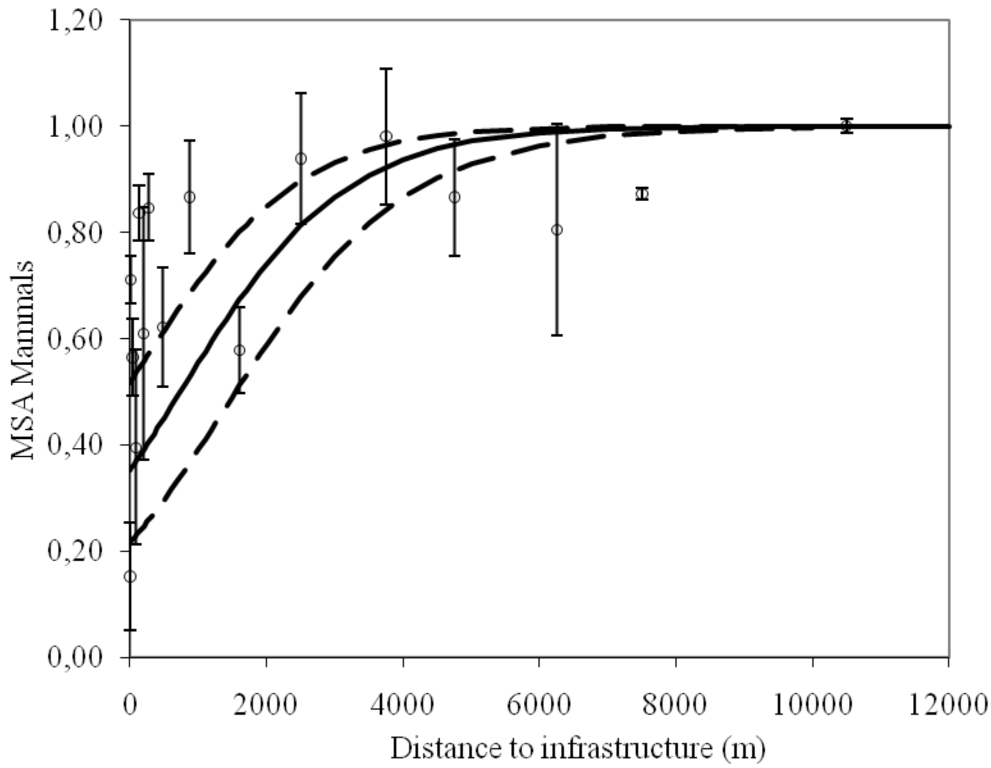


Figure 2. Logistic regression between mean species abundance of mammals and distance from infrastructure. Open dots represent the pooled results of the meta-analysis per distance interval ± S.E. The black line denotes the estimated curve for the decline of MSA, related to distance. Dashed lines are the 95% upper and lower limits of the confidence bands of the curve.

There existed also differences in the relationship between MSA and distance to infrastructure for different taxa. Accitriformes and Falconiformes were the only bird taxa which were unaffected or positively affected by the presence of infrastructure, whereas for the other bird taxa proximity to infrastructure seemed to exert a negative effect on species abundance, or the magnitude of the effect was unknown due to low sample size (Table 10). From all mammal taxa, a positive relationship between MSA and distance to infrastructure could only be found for Artiodactyla and Rodentia, but abundances of the latter were only reduced at short distances from infrastructure while this effect extended over a large distance for the former.

Several *ad hoc* models were built to explore the high heterogeneity between effect sizes. We worked on several biological hypotheses to explain the variability in the relationship between MSA and distance to infrastructure. For bird species the most parsimonious model was that containing only the explanatory variable “LOGDIST” (Akaike weight: 0.78, Table 5). For mammal species the most parsimonious model was that including the explanatory variables “DIST” and “FOR” (Akaike weight: 0.84, Table 6).

The most parsimonious model for the subset of bird data containing information on traffic intensity was that including only “LOGDIST” as explanatory variable (Akaike weight: 0.99, Table 7).

Table 5. Models expressing different biological hypotheses on the influence of infrastructure distance, infrastructure type and infrastructure visibility (forest) on the mean species abundance of birds. The selected model appears in bold.

Model (birds)	**AICc**	**K**	**n**	**Δ_iAICc**	**w_i**
LOGDIST + FOR + INFTYP + LOGDIST * INFTYP + LOGDIST * FOR + FOR * INFTYP + LOGDIST * INFTYP * FOR	No model convergence				
LOGDIST + FOR + LOGDIST * FOR	1630.78	6	288	3.04	0.17
LOGDIST + INFTYP + LOGDIST * INFTYP	1636.04	6	288	8.30	0.01
LOGDIST + FOR	1633.96	5	288	6.21	0.03
LOGDIST + INFTYP	1637.29	5	288	9.54	0.01
LOGDIST	**1627.75**	**4**	**288**	**0.00**	**0.78**
FOR	1647.18	4	288	19.43	<0.01
INFTYP	1646.40	4	288	18.65	<0.01
DIST + FOR + DIST * FOR	1762.19	6	288	134.45	<0.01
DIST + FOR	1744.61	5	288	116.86	<0.01
DIST	1739.98	4	288	112.23	<0.01

AICc= Akaike information criterion corrected for sample size
K= no. of estimable parameters: Intercept, log(effect distance), Effect Distance, Forest, Infra.Type, Interaction term, Study and Error term;
n = nº of data points
Δ_iAICc: Delta AICc value
wi: Akaike Weight.

Table 6. Models expressing different biological hypotheses on the influence of infrastructure distance, infrastructure type and infrastructure visibility (forest) on the mean species abundance of birds. The selected model appears in bold. See Table 5 for explanation of coefficients.

Model (mammals)	**AICc**	**K**	**n**	**Δ_iAICc**	**wi**
LOGDIST + FOR + INFTYP + LOGDIST * INFTYP + LOGDIST * FOR + FOR * INFTYP + LOGDIST * INFTYP * FOR	889.18	10	151	3.59	0.14
LOGDIST + INFTYP + LOGDIST * INFTYP	963.06	6	151	77.50	<0.01
LOGDIST + FOR + LOGDIST * FOR	900.02	6	151	14.46	<0.01
LOGDIST + LOGDIST	919.67	5	151	34.12	<0.01
LOGDIST + FOR	911.34	5	151	25.79	<0.01
LOGDIST	923.42	4	151	37.87	<0.01
INFTYP	896.93	4	151	11.38	<0.01
FOR	899.30	4	151	13.75	<0.01
DIST + FOR + INFTYP + DIST * INFTYP + DIST * FOR + FOR * INFTYP + DIST * INFTYP * FOR	1081.87	10	151	196.28	<0.01
DIST + FOR + DIST * FOR	964.56	6	151	79.01	<0.01
DIST + INFTYP	893.28	5	151	7.73	0.02
DIST + FOR	**885.54**	**5**	**151**	**0.00**	**0.84**
DIST	897.99	4	151	12.45	<0.01

Table 7. Models expressing different biological hypotheses on the influence of infrastructure distance, traffic volume (noise) and infrastructure visibility (forest) on the mean species abundance of birds. The selected model appears in bold. See Table 5 for explanation of coefficients.

Model (birds)	**AICc**	**K**	**n**	**Δ_iAICc**	**w_i**
LOGDIST + FOR + TRAF + LOGDIST * TRAF + LOGDIST * FOR + FOR * TRAF + LOGDIST * TRAF * FOR	583.52	10	87	10.87	<0.01
LOGDIST + TRAF + LOGDIST * TRAF	512.30	6	87	31.65	<0.01
LOGDIST + TRAF	503.06	5	87	22.40	<0.01
TRAF	537.10	4	87	56.44	<0.01
LOGDIST	**480.66**	**4**	**87**	**0.00**	**0.99**

Table 8. Univariate meta-regression coefficients for the relationship between MSA and distance for bird species in different habitats. Models with log-transformed distance as explanatory variable are more parsimonious than without transformation for all habitats.

Bird species							
Explanatory variable	**Habitat**	**b**	**Intercept**	**k**	**n**	**K**	**AICc**
LOGDIST	Agricultural lands	1.523	-7.933	15	109	4	626.29
	Temperate forests	0.761	-2.868	8	35	4	192.57
	Boreal forests	No model convergence		1	2		
	Mediterranean forests	27.020	-136.950	2	4	4	-12.28
	Grasslands	1.014	-5.193	15	97	4	417.24
	Scrublands	1.174	-4.853	5	35	4	200.84
	Tropical forests	18.834	-61.705	3	6	4	80.13
	All forests	0.826	-2.770	14	47	4	263.04
	Non-forested habitats	1.333	-6.712	35	241	4	1361.75
DIST	Agricultural lands	0.005	-1.777	15	109	4	779.75
	Temperate forests	No model convergence		8	35	4	
	Boreal forests	No model convergence		1	2		
	Mediterranean forests	0.046	3.222	2	4	4	0.45
	Grasslands	0.002	-0.759	15	97	4	488.01
	Scrublands	No model convergence		5	35	4	
	Tropical forests	0.522	-17.254	3	6	4	97.57
	Forests	0.011	-0.894	14	47	4	301.93
	Non-forested habitats	0.004	-1.218	35	241	4	1478.68

Table 9. Univariate metaregression coefficients for the relationship between MSA and distance for mammal species in different habitats. Models with log-transformed distance as explanatory variable are more parsimonious than without transformation for all habitats except for tundra.

Mammal species

Explanatory variable	Habitat	b	Intercept	k	n	K	AICc
LOGDIST	Agricultural lands	no model convergence		2	9		
	Temperate forests	0.260	0.103	4	15	4	67.99
	Boreal forests	1.526	-7.742	9	34	4	162.23
	Grasslands			*1*	*5*		
	Scrublands	2.133	-6.773	3	11	4	59.19
	Tropical forests	0.681	-1.136	5	22	4	81.39
	Semi-arid lands			*1*	*8*		
	Arctic tundra	2.854	-21.429	12	52	4	364.50
	All except for Tundra	0.978	-3.670	25	104	4	528.05
	Forests	0.860	-3.151	18	71	4	313.90
	Non-forested habitats	1.142	-7.089	19	85	4	548.28
DIST	Agricultural lands	no model convergence		2	9		
	Temperate forests	0.002	0.850	4	15	4	75.91
	Boreal forests	no model convergence					
	Grasslands	Only 1 dataset		*1*	*5*		
	Scrublands	no model convergence			4		
	Tropical forests	0.003	0.592	5	22	4	107.2
	Semi-arid lands			*1*	*8*		
	Arctic tundra	0.001	-1.832	12	52	4	332.68
	All except for Tundra	0.004	-0.478	25	104	4	614.09
	Forests	0.003	-0.026	18	71	4	397.21
	Non-forested habitats	0.001	-1.659	19	85	4	561.76

Table 10. Univariate metaregression coefficients for different bird and mammal taxa.

Explanatory variable	Bird Taxon	b	Intercept(a)	K	N	AICc	Effect
LOGDIST	Accipitriforme	-1.118	5.249	11	73	532.68	Positive
DIST	Accipitriforme	-0.004	0.820	11	73	607.82	Positive
LOGDIST	Anseriforme	1.681	-8.289	15	145	1064.12	Negative
DIST	Anseriforme	0.008	-2.121	15	145	1056.03	Negative
LOGDIST	Apodiforme	14.253	-21.691	4	8	79.54	Model unstable. Small sample size
DIST	Apodiforme	0.146	20.564	4	8	88.57	Model unstable. Small sample size
LOGDIST	Charadriiforme	1.017	-5.370	11	136	830.27	Negative
DIST	Charadriiforme	0.002	-0.491	11	136	795.72	Negative
LOGDIST or DIST	Columbiforme	no model convergence		9	55		Unknown
LOGDIST or DIST	Coraciiforme	Only 1 dataset		1	2		Unknown
LOGDIST	Cuculiforme	0.428	-1.539	4	18	83.79	Negative. Small sample size.
DIST	Cuculiforme	no model convergence					Unknown
LOGDIST	Falconiforme	-0.672	4.265	7	21	126.36	Positive
DIST	Falconiforme	-0.003	1.747	7	21	136.11	Positive
LOGDIST or DIST	Galliforme	no model convergence		7	45		Unknown
LOGDIST	Gruiforme	1.284	-7.940	7	47	251.18	Negative for Otis tarda (6 datasets)
DIST	Gruiforme	0.003	-1.594	7	47	251.19	Negative for Otis tarda (6 datasets)
LOGDIST	Passeriforme	0.729	-2.776	21	1167	7628.47	Negative
DIST	Passeriforme	0.009	-0.951	21	1167	11026.08	Negative
LOGDIST	Piciforme	0.484	-2.110	5	50	233.71	Negative
DIST	Piciforme	0.007	-0.997	5	50	248.22	Negative
LOGDIST or DIST	Psittaciforme	Only 1 dataset		1	6		Unknown. Low sample size
LOGDIST or DIST	Trochiliforme	Only 1 dataset		1	44		Unknown. Low sample size

Explanatory variable	Mammal Taxon	b	Intercept(a)	k	n	AICc	Effect
LOGDIST	Artiodactyla	1.441	-8.583	25	127	712.29	Negative
DIST	Artiodactyla	0.0008	-0.9885	25	128	691.59	Negative
LOGDIST or DIST	Carnivora	no model convergence		7	28		Unknown
LOGDIST or DIST	Lagomorpha	Only 1 dataset		1	5		Unknown
LOGDIST or DIST	Perissodactyla	Only 1 dataset		1	5		Unknown
LOGDIST	Proboscidea	no model convergence		2	10		Unknown

DIST	Proboscidea	0.003	-2.071	2	10	65.01	Neutral. Low sample size
LOGDIST	Rodentia	0.263	0.421	9	115		Negative
DIST	Rodentia	0.003	0.746	9	115	633.10	Negative

4.3. Outcome of the review

The analysis of the selected studies helped us to find out that mammal and bird population densities significantly declined with their proximity to infrastructure. Bird populations were reduced at a shorter distance to infrastructure than mammal populations. Mammals and birds seemed to avoid larger distances from infrastructure in open areas compared to forested areas, which could be related to the reduced visibility of the infrastructure in forested areas. We could not find a significant effect of traffic intensity on the MSA of birds. Species populations responded differently to infrastructure. Raptors were found to be more abundant in the proximity of infrastructure whereas the other bird taxa avoided it. Small-sized mammals were affected within few meters from infrastructure while abundance of large-sized mammals was reduced up to several hundred meters from infrastructure.

5. Discussion

5.1. Effect of distance from infrastructure on bird and mammal species abundance

Our analyses suggest that infrastructure can have a negative impact on bird and mammal abundance and that this impact is more evident in the proximity of the infrastructure. Pooled results for pseudorreplicated data indicated a decline in species abundance of 28-36% and 25-38% for birds and mammals within 2.5km and 17km from infrastructure, respectively. Pooled results per distance interval showed that MSA of birds and of mammals became higher for distance intervals far away from infrastructure. The meta-regression also indicated a positive relationship between MSA of birds and mammals and distance to infrastructure. A second conclusion that can be obtained from these results is that bird populations are likely to be more affected at short distances from infrastructure while the effect on mammal populations seems to extend over larger distances. These results confirm the effect distances reported in other studies, which were larger for mammals (Cameron et al., 1992; Newmark et al., 1996; Nellemann et al., 2003a; Joly et al., 2006) than for birds (Zande *et al*. 1980; Madsen, 1985; Reijnen et al., 1996; Rheindt, 2003). However, considerable heterogeneity was found in our results, especially for birds, and also publication bias, both limiting the robustness of these conclusions.

The sensitivity analyses resulted in a slightly (but not statistically significant) larger pooled effect size for pseudorreplicated data in the case of bird species. Sensitivity analyses per distance interval showed similar results to the full meta-analyses except for the distance intervals between 300 and 480 m from infrastructure, with larger effect sizes. Yet, fail-safe numbers indicate that a large number of non-significant studies would be needed to overturn the pooled effect sizes calculated for these distance intervals. Thus, we decided to maintain these studies in the meta-regression following Wolf and Guevara (2001), who advocate for the use of all available data when doing meta-analysis.

The high heterogeneity underlying the results of our meta-analysis indicates that infrastructure development can have negative impacts on bird and mammal abundance within a certain distance depending on a number of factors which we further explore in section 5.2.

5.2. Exploration of reasons for heterogeneity

Meta-regression helped us to elucidate that “LOGDIST” was the main explanatory variable for the decline in abundance of bird populations due to infrastructure. For mammals, “DIST” was the main variable but the variable “FOR” seemed to add important information to the model. Meta-regression on subgroups divided by habitat type and taxa indicated that in open habitats, both mammal and bird populations seem to avoid infrastructure over larger distances, compared to those in forested biomes, which could probably be related to reduced visibility of infrastructure. Forman and Deblinger (2000) showed similar results for breeding birds in open grasslands and in woodlands (data adapted from Reijnen et al., 1995, 1996).

For the subset of bird data including information on traffic intensity, the most parsimonious model was that which contained only “LOGDIST” as explanatory variable. Therefore it seems that traffic intensity has no effect on the reduction of bird populations nearby roads. These results are contrary to the findings of a number of authors that have highlighted the pernicious effects of traffic intensity and noise on bird populations (Reijnen and Foppen, 1994; Reijnen et al., 1995, 1996 and 1997; Forman et al., 2002; Rheindt, 2003). However, there are other studies which found a decline in bird populations near roads with low traffic intensity (Räty, 1979; Madsen, 1985, Develey et al., 2001) and others which found no clear relationship (Peris and Pescador, 2004). Finally, some authors claim that there exists a trade-off between traffic intensity and velocity, with low traffic intensity being related to higher velocities (Martinez-Abrain, 1994; Drews, 1995). Yet, traffic velocity seems to be related to bird mortality, which occurs on the road itself. To the best of our knowledge, studies that deal with this topic usually do not report on bird densities at increasing distances from roads (or include a control distance for comparison). As none of the studies included in our analysis contained data on traffic velocity, the influence of this variable could not be evaluated.

Not all species showed a decline in abundance nearby infrastructure: species abundance of Accipitriformes and Falconiformes was larger in the proximity of infrastructure. This was not a surprising outcome since other studies have reported the presence of raptors nearby roads searching roadkill carrion (Forman and Alexander, 1998, Lambertucci et al., 2009) and hunting (Donazar et al. 1993; Fajardo et al., 1998; Dean and Milton, 2003), with some exceptions during the breeding season (Martinez-Abrain et al., 2008).

In the case of mammals, we could detect that Rodentia populations were slightly affected within few meters from infrastructure. By contrast, Artiodactyla species were affected up to distances of several hundred meters. Within Artiodactyla wild reindeer (*Rangifer tarandus*) was one of the most studied and sensitive species, with their population abundance being reduced up to several kilometres from infrastructure (Nellemann and Cameron, 1996; Nellemann et al., 2001, Nellemann et al., 2003). These outcomes are consistent with the fact that small-sized mammals usually have smaller home ranges and migration distances compared to medium- and large-sized mammals, the latter being more sensitive to infrastructure development and habitat fragmentation (Harestad and Bunnel, 1979; Buskirk, 2009).

5.3. Review limitations

Only some of the included studies used BACI (Before-After-Control-Impact) experimental designs, so we decided to use the largest reported distance in the study as control distance. Although the sensitivity analyses allowed us to remove some of the studies of lower quality and indeed the results did not vary in most of the cases, we acknowledge that our conclusions are restricted by the lack of proper comparators in some of the studies.

The identified publication bias is another of the weaknesses of our review. A few studies did not find negative effects of infrastructure on bird and mammal populations and were not included due to lack of proper data on the selected variables (e.g. Adams, 1984; Evans and Gates, 1997; Ballard et al., 2000); and there may exist many others that were never published due to non-significant results or that we were unable to obtain (grey literature). However, fail-safe numbers indicated that our results are sufficiently robust.

Many of the studies initially considered in our systematic review lacked suitable data for extraction and had to be left out of the analysis. Therefore we may have excluded potentially relevant studies and included lower quality studies due to availability of data on the selected variables.

The scope of the study was intended to be global and covered different types of biomes and habitats; nevertheless there is a geographical bias in the studies included in our review. Most studies were done in Europe and North America and therefore the applicability of the results to other geographic areas remains unknown.

6. Reviewers' Conclusions

6.1 Implications for conservation and policy

The results of our meta-analysis will be implemented in the next version of the GLOBIO3 model, which is used to estimate the biodiversity loss at global, regional and national level at current state and for possible future scenarios and policy options (Alkemade et al., 2009). The results of the GLOBIO3 model have been reported in global assessments such as the second Global Biodiversity Outlook and the fourth Global environmental Outlook and are aimed to support policy makers on the elaboration of biodiversity conservation policies (sCBD and MNP, 2007; UNEP, 2007). The method is also used at the regional level (Verboom et al., 2007) and at the country level (e.g. in Viet Nam, Ecuador and Nicaragua)

Our study shows the importance of minimizing infrastructure development for wildlife conservation in relatively undisturbed areas. By combining actual species distributions with the effect distance functions we developed as a form of dose-effect relationship, regions sensitive to infrastructure development may be identified. More specifically, the effect distance functions can be used in models in support of decision making on infrastructure planning. This would mean a substantial improvement of the current situation in which, in most cases, results of previous studies on ecological impacts are barely taken into account (OECD, 2002; Roedenbeck et al., 2007).

6.2 Implications for research

Changes in wildlife populations in proximity of infrastructure have been reported for decades in a number of studies (Table 2), and have been pointed out in relevant authors' reviews (Spellerberg, 1998; Trombulak and Frissell, 2000; Forman et al., 2003). Additionally, there have been previous attempts to quantify wildlife population decline in relation to distance from infrastructure, either locally (Forman and Deblinger, 2000) or at the global scale (UNEP, 2001; Nellemann et al., 2003b; Fahrig and Rytwinski, 2009), but none of them followed the guidelines for systematic reviews (Pullin and Stewart, 2006) or summarized the information by means of a meta-analysis. Our study represents a step forward within the field of road ecology research that may contribute to the understanding of the magnitude of the pernicious effects of infrastructure development on animal populations. Reported effects for most bird populations extend over distances up to about 1 kilometre, and for most mammal populations up to about 5 kilometres, with variation according to taxa and habitat type (Fig. 1 and 2). However, the evidence shown by our results is somewhat hampered by the limitations mentioned in the section 4.3. We therefore encourage researchers to perform BACI studies whenever possible and make their data available for researchers pursuing a systematic review. Should new studies that include these recommendations be released in future, the review can be updated by including the new available evidence.

Although the patterns found in our analysis are clear, we would like to emphasise that these only represent a partial estimate of the actual effect of infrastructure on wildlife. Therefore, we highlight the importance of broadening the analysis to other taxonomic groups, such as herpetofauna, plants and invertebrates (e.g.: Przybylski, 1979; Angold, 1997; Auerbach et al., 1997; Haskell, 2000; Shine et al., 2004; Barrows et al., 2006). Further research on these taxonomic groups would add up to the current models presented in this study, contributing to eventually produce a model that would provide an accurate estimate of the effects of infrastructure development on biodiversity.

7. Acknowledgements

We thank Christian Nellemann of NINA and Rien Reijnen of Alterra for their useful comments in an early stage of the paper. Hendriek Boshuizen provided her expertise with the meta-analysis. The text was improved by Annemieke Righart, the English text editor at the Netherlands Environmental Assessment Agency (PBL). We also thank two anonymous reviewers whose comments improved this systematic review.

8. Potential Conflicts of Interest and Sources of Support

No potential conflicts of interest declared.

9. References

Adams, L.W. 1984. Small mammal use of an interstate highway median strip. Journal of Applied Ecology, 21, 175-178.

Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. Australian Zoologist, 26, 130-141.

Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M., ten Brink, B. 2009. GLOBIO3: A Framework to investigate options for reducing global terrestrial biodiversity loss. Ecosystems, 12, 374-390.

Angold, P.G. 1997. The impact of a road upon adjacent heathland vegetation: effects on plant species composition. Journal of Applied Ecology, 34, 409-417.

Arnqvist, G., Wooster, D. 1995. Meta-analysis: synthesizing research findings in ecology and evolution. Trends in Ecology and Evolution, 10, 236-240.

Auerbach, N.A., Walker, M.D., Walker, D.A. 1997. Effects of roadside disturbance on substrate and vegetation properties in Arctic Tundra. Ecological Applications, 7, 218-235.

Ballard, W.B., Cronin, M.A., Rodrigues, R., Skoog, R.O., Pollard, R.H. 2000. Arctic fox, *Alopex galopus*, den densities in the Prudhoe Bay Oil Field, Alaska. Canadian Field-Naturalist, 114, 453-456.

Ballasus. H., Sossinka, R. 1997. The impact of power lines on field selection and grazing intensity of wintering White-fronted- and Bean Geese *Anser albifrons, A. fabalis.* Journal für Ornithologie. 138: 215-228.

Barrios, L., Rodriguez, A. 2004.Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. Journal of Applied Ecology, 41, 72-81.

Barrows, C.W., Allen, M.F., Rotenberry, J.T. 2006. Boundary processes between a desert sand dune community and an encroaching suburban landscape. Biological Conservation, 131, 486-494.

Bates, D., Maechler, M. 2009. lme4: Linear mixed-effects models using S4 classes. R package version 0.999375-31. http://CRAN.R-project.org/package=lme4

Bautista, L.M., García, J.T., Calmaestra, R.G., Palacin, C., Martín, C.A., Morales, M.B., Bonal, R., Viñuela, J. 2004. Effect of weekend road traffic on the use of space by raptors. Conservation Biology, 18: 726-732.

Bolger, D.T., Scott, T.A., Rotenberry, J.T. 1997. Breeding bird abundance in an urbanizing landscape in coastal Southern California. Conservation Biology, 11, 406-421.

Boarman, W.I., Sazaki, M. 2005. A highway's road-effect for desert tortoises (*Gopherus agasazii*). Journal of Arid Environments, 65, 94-101.

Buskirk, S. 2009. Keeping an eye on the neighbours. Science, 306, 238-239.

Cameron, R.D., Reed, D.J., Dau, J.R., Smith, W.T. 1992. Redistribution of calving caribou in response to oil field development on the Arctic Slope of Alaska. Arctic, 45, 338-342.

Carbaugh, B., Vaughan, J.P., Bellis, E.D., Graves, H.B. 1975. Distribution and activity of white-tailed deer along an interstate highway. Journal of Wildlife Management, 39, 570-581.

Clark, W.D., Karr, J.R. 1979. Effects of highways on Red-winged Blackbird and Horned Lark populations. Wilson Bulletin, 81, 143-145.

Cox, D.R.1970. The analysis of binary data. Methuen & Co Ltd, London.

Cronin, M.A., Amstrup, S.C., Durner, G.M., Noel, L.E., McDonald, T.L., Ballard, W. 1998. Caribou distribution during the post-calving period in relation to infrastructure in the Prudhoe Bay oil field, Alaska. Arctic, 51, 85-93.

Dean, W.R.J., Milton, S.J. 2003. The importance of roads and road verges for raptors and crows in the Succulent and Nama-Karoo, South Africa. Ostrich, 74, 181-186.

Delgado, J.D., Arévalo, J.R., Fernández-Palacios, J.M. 2004. Consecuencias de la fragmentación viaria: Efectos de borde de las carreteras en la laurisilva y el pinar de Tenerife., in: Fernández-Palacios, J.M., Morici, C.(Eds.), Ecología Insular/Island Ecology. Asociación Española de Ecología Terrestre (AEET)-Cabildo Insular de La Palma, pp. 181-225.

DerSimonian, R., Laird, N. 1986. Meta-analysis in clinical trials. Controlled Clinical Trials, 7, 177-188.

Develey, P.F., Stouffer, P.C. 2001. Effects of roads on movements by understorey birds in mixed-species flocks in Central Amazonian Brazil. Conservation Biology, 15, 1416-1422.

Devereux, C.L., Denny, M.J.H., Whittingham, M.J. 2008. Minimal effects of wind turbines on the distribution of wintering farmland birds. Journal of Applied Ecology 45, 1689-1694.

Donazar, J.A., Ceballos, O., Travaini, A., Hiraldo, F. 1993. Roadside raptor surveys in the Argentinean Patagonia. Journal of Raptor Research, 27, 106-110.

Drews, C. 1995. Road kills of animals by public traffic in Mikumi National Park, Tanzania, with notes on baboon mortality. African Journal of Ecology, 33, 89-100.

Dunthorn, A.A., Errington, F.P. 1964. Casualties among birds along a selected road in Wiltshire. Bird study, 11, 168-182.

Dyer, S.J., O'Neill, J.P., Wasel, S.M., Boutin, S. 2001. Avoidance of industrial development by woodland caribou. Journal of wildlife management, 65, 531-542.

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

Evans, D.R., Gates, E.J. 1997. Cowbird selection of breeding areas: The role of habitat and bird species abundance. Wilson Bulletin, 109, 470-480.

Fahrig, L. and Rytwinski, T. 2009 Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society, 14, 21
URL: http://www.ecologyandsociety.org/vol14/iss1/art21/

Fajardo, I., Pividal, V., Trigo, M., Jimenez, M. 1998. Habitat selection, activity peaks and strategies to avoid road mortality by the little owl, a new methodology on owls research. Alauda 66, 49-60.

Forman, R.T.T., Alexander, L.E. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics, 29, 207-231.

Forman, R.T.T., Deblinger, R.D. 2000. The ecological road-effect zone of Massachusetts (U.S.A.) suburban highway. Conservation Biology, 14, 36-46.

Forman, R.T.T., Reineking, B., Hersperger, A.M. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. Environmental Management, 29, 782-800.

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R., Goldman, C.R, Heanue, K., Jones, J.A., Swanson, F.J., Turrentine, T., Winter, T.C. 2003. Road ecology: Science and solutions. Island Press, Washington, Covelo, London.

Gagnon, J.W., Theimer, T.C., Dodd, N.L., Boe, S., Schweinsburg, R.E. 2007. Traffic volume alters elk distribution and highway crossings in Arizona. Journal of Wildlife Management, 71, 2318-2323.

Gill, J.A., Sutherland, W.J., Watkinson, A.R. 1996. A method to quantify the effects of human disturbance on animal populations. Journal of Applied Ecology, 33, 786-792.

Goosem, M., Marsh, H. 1997. Fragmentation of a small-mammal community by a powerline corridor through tropical rainforest. Wildlife Research 24, 613-629.

Gullison, R.E., Hardner, J.J. 1993. The effects of road design and harvest intensity on forest damage caused by selective logging: empirical results and a simulation model from the Bosque Chimanes, Bolivia. Forest Ecology and Management, 59, l-14.

Harestad, A.S., Bunnel, F.L. 1979. Home range and body weight—A reevaluation. Ecology, 60, 389-402.

Haskell, D.G. 2000. Effects of roads on macroinvertebrate soil fauna of the Southern Appalachian Mountains. Conservation Biology, 14, 57-63.

Hüppop, V.O., Hüppop, K, 1995. The influence of agriculture and road usage on the distribution of coastal bird nests on saltmarshes in Schleswig-Holstein (Germany). Die Vogelwarte, 38, 76-88.

Jaeger, J.A.G., Bowman, J., Brennan, J., Fahrig, L. Bert, D., Bouchard, J., Charbonneau, N., Frank, K., Gruber, B., von Toschanowitz, K.T. 2005. Predicting when animal populations are at risk from roads: an interactive model of road avoidance behavior. Ecological modeling, 185, 329-348.

Joly, K., Nellemann, C., Vistnes, I. 2006. A reevaluation of caribou distribution near an oilfield road on Alaska's North Slope. Wildlife Society Bulletin, 34, 866-869.

Keller, V.E. 1991.The effect of disturbance from roads on the distribution of feeding sites of geese *(Anser brachyrhynchus, A. anser),* wintering in North-Scotland. Ardea 79. 229-232.

Kroodsma, R.L. 1984. Effect of edge on breeding forest bird species. Wilson Bulletin, 96, 426-436.

Kuitunen, M., Rossi, E., Stenroos, A. 1998. Do highways influence density of land birds? Environmental Management, 22, 297-302.

Lambertucci, S.A., Speziale, K.L., Rogers, T.A., Morales, J.M. 2009. How do roads affect the habitat use of an assemblage of scavenging raptors? Biodiversity and Conservation, 18, 2063-2074.

Lane, S.J., Alonso, J.C., Martín, C.A. 2001. Habitat preferences of great bustard *Otis tarda* flocks in the arable steppes of central Spain: are potentially suitable areas unoccupied? Journal of Applied Ecology, 38, 193-203.

Larsen, J.K., Madsen, J. 2000. Effects of wind turbines and other physical elements on field utilization by pink-footed geese (*Anser brachyrhynchus*): A landscape perspective. Landscape Ecology, 15, 755-764.

Laurance, W.F., Croes, B.M., Tchignoumba, L., Lahm, S.A., Alonso, A., Lee, M.E., Campbell, P., Ondzeano, C. 2006. Impacts of roads and hunting on central African rainforest mammals. Conservation Biology, 20, 1251-1261.

Lockwood, J.L., McKinney M.L. 2001. Biotic Homogenization. Kluwer Academic/Plenum Publishers.

Madsen, J. 1985. Impact of disturbance on field utilization of Pink-footed geese in West Jutland, Denmark. Biological Conservation, 33, 53-63.

Mahoney, S.P., Schaefer, J.A. 2002. Hydroelectric development and the disruption of migration in caribou. Biological Conservation, 107, 147-153.

Malcolm, J.R., Ray, J.C. 2000. Influence of timber extraction routes on Central African small-mammal communities, forest structure and tree diversity. Conservation Biology, 14, 1623-1638.

Martinez-Abrain, A. 1994. Mortalidad estacional de aves en una carretera del P.N. de l'Albufera de Valencia (E. España). Doñana, Acta Vertebrata, 21, 90-95.

Martínez-Abraín, A., Oro, D., Jiménez, J., Stewart, G. & Pullin, A. 2008. What are the impacts of human recreational activity on the distribution, nest-occupancy rates and reproductive success of breeding raptors? Systematic Review No. 27. Collaboration for Environmental Evidence.

McLellan, B. N., Shackleton, D. M. 1989. Grizzly bear and resource extraction industries: habitat displacement in response to seismic exploration, timber harvesting and road maintenance. Journal of Applied Ecology, 26, 371-380.

Meunier, F.D., Verheyden, C., Jouventin, P. 1999. Bird communities of highway verges: influence of adjacent habitat and roadside management. Acta Oecologica, 20, 1-13.

Meunier, F.D., Verheyden, C., Jouventin, P. 2000. Use of roadsides by diurnal raptors in agricultural landscapes. Biological Conservation, 92, 291-298.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human well-being: Biodiversity Synthesis. Island press, Washington DC.

Mood, A.M., Graybill, F.A., Boes, D.C. 1973. Introduction and theory of statistics, 3rd edn. McGraw-Hill, Auckland.

Nellemann, C., Cameron, R.D. 1996. Effects of petroleum development on terrain preferences of calving caribou. Arctic, 49, 23-28.

Nellemann, C., Vistnes, I. Jordhøy, P., Strand, O. 2001. Winter distribution of wild reindeer in relation to powerlines, roads and resorts. Biological Conservation, 101, 351-360.

Nellemann, C., Jordhøy, P., Vistnes, I., Strand, O., Newton, A. 2003a. Progressive impacts of piecemeal development. Biological Conservation, 113, 307–317.

Nellemann, C., Vistnes, I., Ahlenius, H., Rekazewicz, P., Kaltenborn, B.P., Magomedova, M., Udovyk, O., Furuhovde, T. 2003b. Environment and security: 2050 scenarios. Social and Environmental Impacts in the North (eds R.O. Rasmussen & N.E. Koroleva), pp 129-148. Kluwer Academic Publishers.

Newmark, W.D., Boshe, J.I., Sariko, H.I., Makumbule, G.K. 1996. Effects of a highway on large mammals in Mikumi National Park, Tanzania. African Journal of Ecology, 34, 15-31.

Noel, L.E., Parker, F.R., Cronin, M.A. 2004. Caribou distribution near an oilfield road on Alaska's North Slope, 1978-2001. Widlife Society Bulletin, 32, 757-771.

OECD. 2002. OECD guidelines towards environmentally sustainable transport. OECD Publications, Paris.

Oehler, J.D., Litvaitis, J.A. 1996. The role of spatial scale in understanding responses of medium-sized carnivores to forest fragmentation. Canadian Journal of Zoology, 74, 2070-2079.

Oehlert, G.W. 1992. A note on the Delta Method. The American Statistician, 46, 27-29.

Ortega, Y.K., Capen, D.E. 1999. Effects of forest roads on habitat quality for Ovenbirds in a forested landscape. Auk, 116, 937-946.

Osenberg, C.W., Sarnelle, O., Cooper, S.D., Holt, R.D. 1999. Resolving ecological questions through meta-analysis: goals, metrics, and models. Ecology, 80, 1105-1117.

Parris, K.M., Schneider, A. 2009. Impacts of traffic noise and traffic volume on birds of roadside habitats. Ecology and Society, 14:29.
URL: http://www.ecologyandsociety.org/vol14/iss1/art29/

Paruk, J.D. 1987. Habitat utilization by bald eagles wintering along the Mississippi River. Transactions or the Illinois Academy of Science, 80, 333-342.

Peris, S.J., Pescador, M. 2004. Effects of traffic noise on passerine populations in Mediterranean wooded pastures. Applied Acoustics, 65, 357-366.

Pimm, S.L., Russell, G.H., Gittleman, J.H., Brooks, T.M. 1995. The future of biodiversity. Science, 269, 347-350.

Pinheiro, J. C., Bates, D. M. 2000. Mixed-effects Models in S and S-PLUS. Springer Verlag, New York.

Piper, S.D., Catterall, C.P. 2006. Impacts of picnic areas on bird assemblages and nest predation activity within Australian eucalypt forests. Landscape and Urban Planning, 78, 251-262.

Przybylski, Z. 1979. The effects of automobile exhaust gases on the arthropods of cultivated plants, meadows and orchards. Environmental Pollution, 19, 157-161.

Pullin, A.S., Stewart, G.S. Guidelines for systematic review in conservation and environmental management. Conservation Biology, 20, 1647-1656.

R Development Core Team. 2009. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Räty, M. 1979. Effect of highway traffic on tetraonid densities. Ornis Finnica, 56, 169-170.

Reed, R.A., Johnson-Barnard, J., Baker, W.L. 1996. Contribution of roads to forest fragmentation in the Rocky Mountains. Conservation Biology, 10, 1098-1106.

Reijnen, R., Foppen, R. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for Willow Warblers (*Phylloscopus trochilus*) breeding close to a highway. Journal of Applied Ecology, 31, 85-94.

Reijnen, R., Foppen, R., Ter Braak, C., Thissen, J. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology, 32, 187-202.

Reijnen, R., Foppen, R., Meeuwsen, H. 1996. The effect of traffic on the density of breeding bird populations in Dutch agricultural grasslands. Biological Conservation, 75, 255-260.

Rheindt, F.E. 2003. The impact of roads on birds: Does song frequency play a role in determining susceptibility to noise pollution? Journal fur Ornithologie, 144, 295-306.

Rich, A.C., Dobkin, D.S., Niles, L.J. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology, 8, 1109-1121.

Roedenbeck, I.A., Fahrig, L., Findlay, C.S., Houlahan, J.E., Jaeger, J.A.G., Klar, N., Kramer-Schadt, S., Van der Grift, E. A. 2007. The Rauischholzhausen agenda for road ecology. Ecology and Society, 12 (1): 11.
URL: http://www.ecologyandsociety.org/vol12/iss1/art11/

Roedenbeck, I.A., Voser, P. 2008. Effects of roads on spatial distribution, abundance and mortality of brown hare (*Lepus europaeus*) in Switzerland. European Journal of Wildlife Research, 54, 425-437.

Romin, L.A., Bissonette, J.A. 1996. Deer-vehicle collisions: Status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin, 24, 276-283.

Rosenthal, R. 1979. The "file drawer problem" and tolerance for null results. Psychological Bulletin, 86, 638–641.

Rost, G.R., Bailey, J.A. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management, 43, 634-641.

Sala, O.E., Chapin III, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Irzo, R., Huber-Samwald, E., Huenneke, K.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., Wall, D.H. 2000. Global biodiversity scenarios for the year 2100. Science, 87, 1770-1774.

Sanderson E.W., Jaiteh M., Levy M.A., Redford K.H., Wannebo A.V., Woolmer G. 2002. The Human footprint and the last of the wild. BioScience, 52, 891-904.

Santos, A.M., Tabarelli, M. 2002. Distance from roads and cities as a predictor of habitat loss and fragmentation in the caatinga vegetation of Brazil. Brazilian Journal of Biology, 62:897-905.

sCBD and MNP. 2007. Cross-roads of life on earth—exploring means to meet the 2010 Biodiversity target. Solution-oriented scenarios for global biodiversity outlook 2. Technical Series no 31. Montreal: Secretariat of the Convention on Biological Diversity. pp 90.

Shine, R., Lemaster, M., Wall, M., Langkilde, T., Mason, R. 2004. Why did the snake cross the road? Effects of roads on movement and location of mates by garter snakes (*Thamnophis sirtalis parietalis*). Ecology and Society, 9, 9
URL: http://www.ecologyandsociety.org/vol9/iss1/art9/

Sokal, R.R., Rohlf, F.J. 1981. Biometry: The principles and practice of statistics in biological research, second ed. Freeman, New York.

Spellerberg, I.F. 1998. Ecological effects of roads and traffic: a literature review. Global Ecology and Biogeography Letters, 7, 317-333.

Sweeting, M.J., Sutton, A.J., Lambert, P. 2004. What to add to nothing? Use and avoidance of continuity corrections in meta-analysis of sparse data. Statistics in Medicine, 23, 1351-1375.

Tigas, L.A., Van Vuren, D.H., Sauvajot, R.M. 2002. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. Biological Conservation, 108, 299-306.

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

Trombulak, S.C., Frissell, C.A. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology, 14, 18-30.

UNEP. 2001. Nellemann, C., Kullerud, L., Vistnes, I., Forbes, B.C., Husby, E., Kofinas, G.P., Kaltenborn, B.P., Rouaud, J., Magomedova, M., Bobiwash, R., Lambrechts, C., Schei, P. J., Tveitdal, S., Grøn, O., Larsen, T. S. GLOBIO. Global methodology for mapping human impacts on the biosphere. UNEP/DEWA/TR.01-3.

UNEP. 2007. Global environmental outlook 4. Environment for development. Nairobi, Kenya: United Nations Environmental Programme.

Van Dyke, F., Klein, W.C. 1996. Response of elk to installation of oil wells. Journal of Mammalogy, 77, 1028-1041.

Van der Zande, A.N., TerKeurs, W.J., van der Weijden, W.J. 1980. The impact of roads on the densities of four bird species in an open field habitat – evidence of a long-distance effect. Biological Conservation, 18, 299-321.

Verboom, J., Alkemade, R., Klijn, J., Metzger, M.J., Reijnen, R. 2007. Combining biodiversity modeling with political and economical development scenarios for 25 countries. Ecological Economics, 62, 267–76.

Viechtbauer, W. 2009. metafor: Meta-Analysis Package for R. R package version 0.5-4. http://CRAN.R-project.org/package=metafor

Vistnes, I., Nellemann, C. 2001. Avoidance of cabins, roads, and power lines by reindeer during calving. Journal of Wildlife Management, 65, 915–925.

Vitousek, P.M. 1994. Beyond global warming: ecology and global change. Ecology, 75, 3-15.

Vos, C.C., Chardon, J.P. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *Rana arvalis*. Journal of Applied Ecology, 35, 44-56.

Winzer, P.J. 2000. Accuracy of error propagation exemplified with ratios of random variables. Review of Scientific Instruments, 71, 1447-1454.

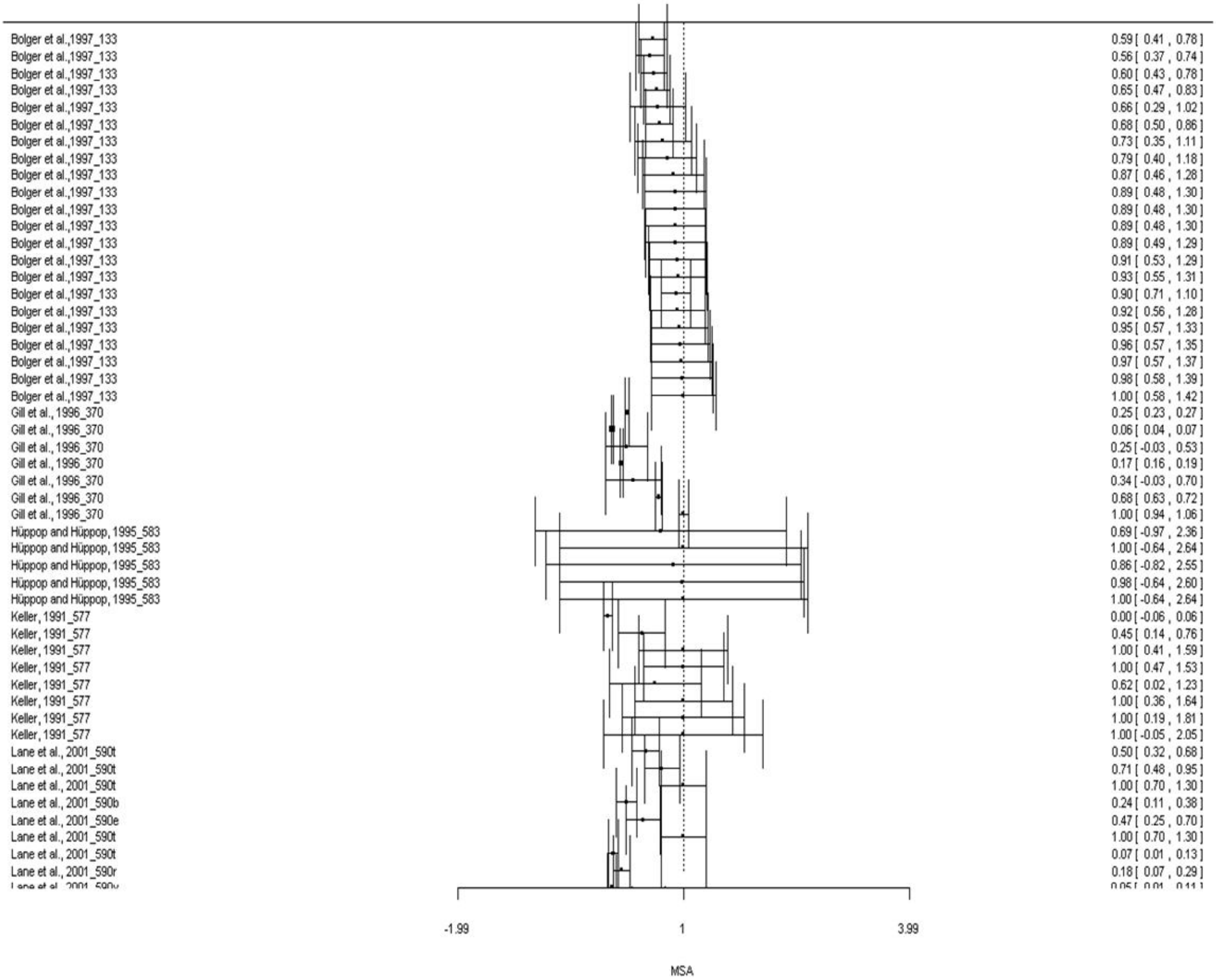
Wolf, F., Guevara, J. 2001. Imputation of missing data in systematic reviews: so what is the standard deviation? Cochrane, 1: pa007.

Yost, A.C., Wright, R.G. 2001. Moose, caribou and grizzly bear distribution in relation to road traffic in Denali National Park, Alaska. Arctic, 54, 41-48.

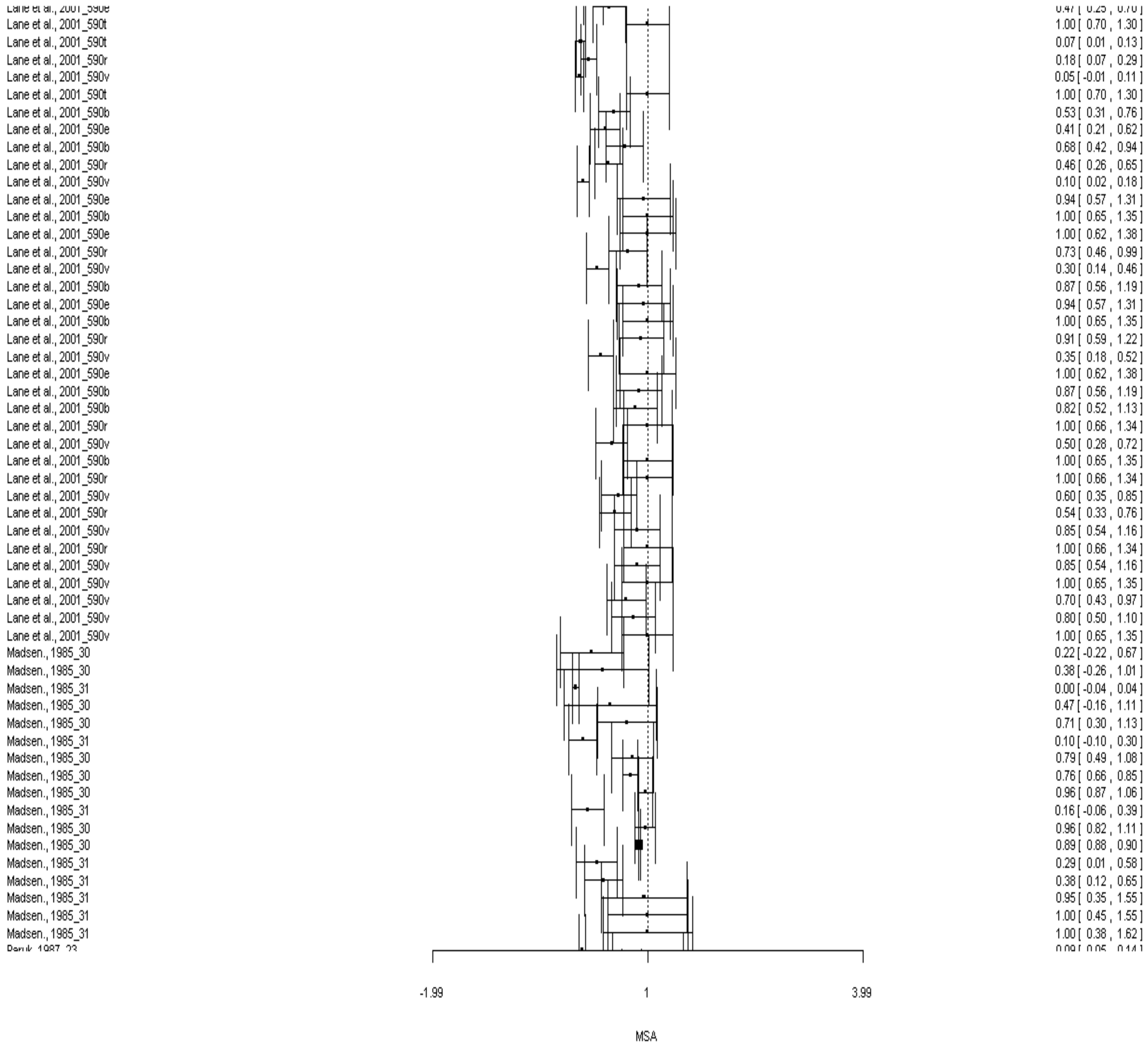
10. Appendices

Appendix 1. Forest and funnel plots with the results of the meta-analysis for bird species for different distance intervals.

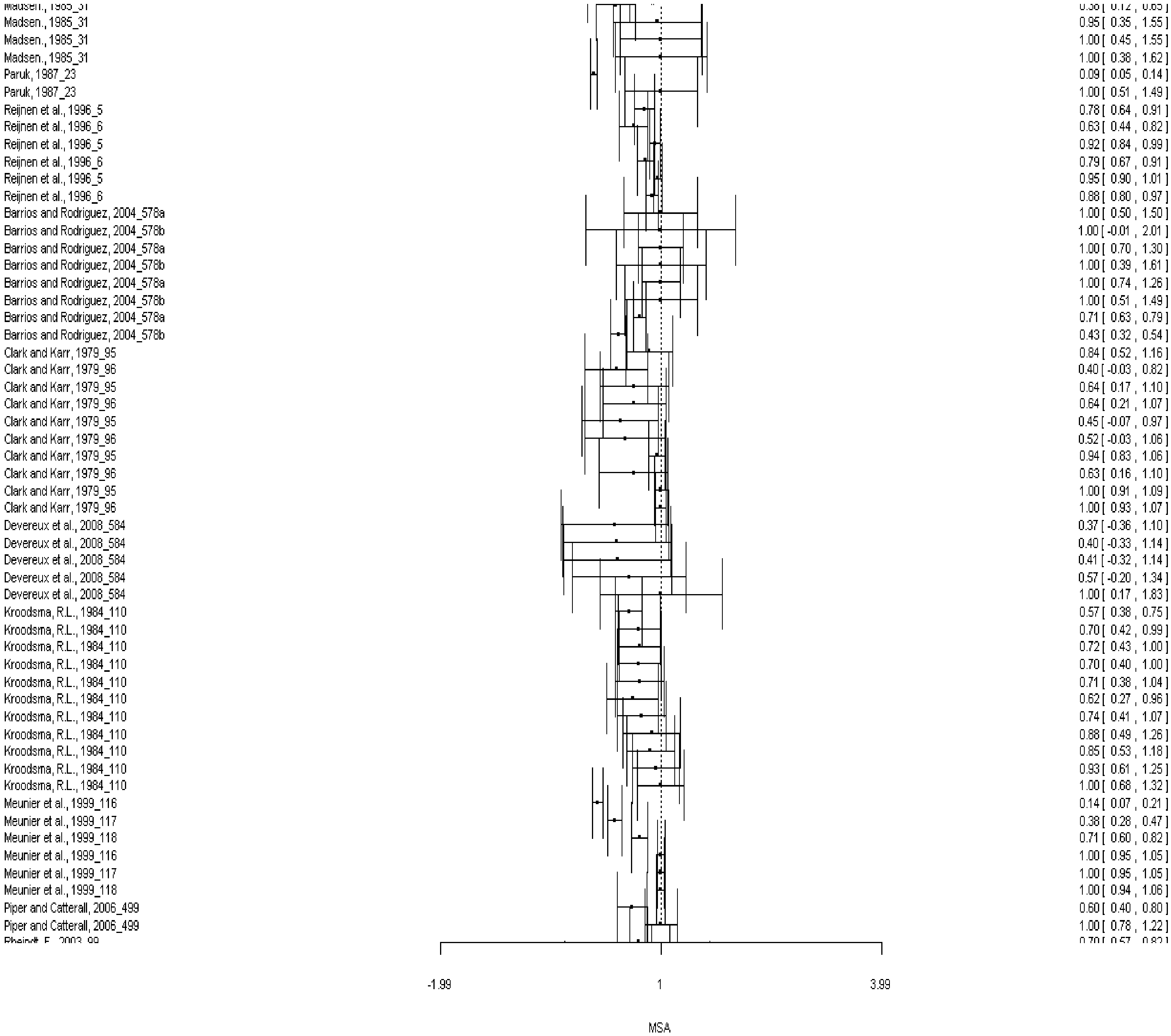
a) First part of the forest plot for the meta-analysis for all distances.



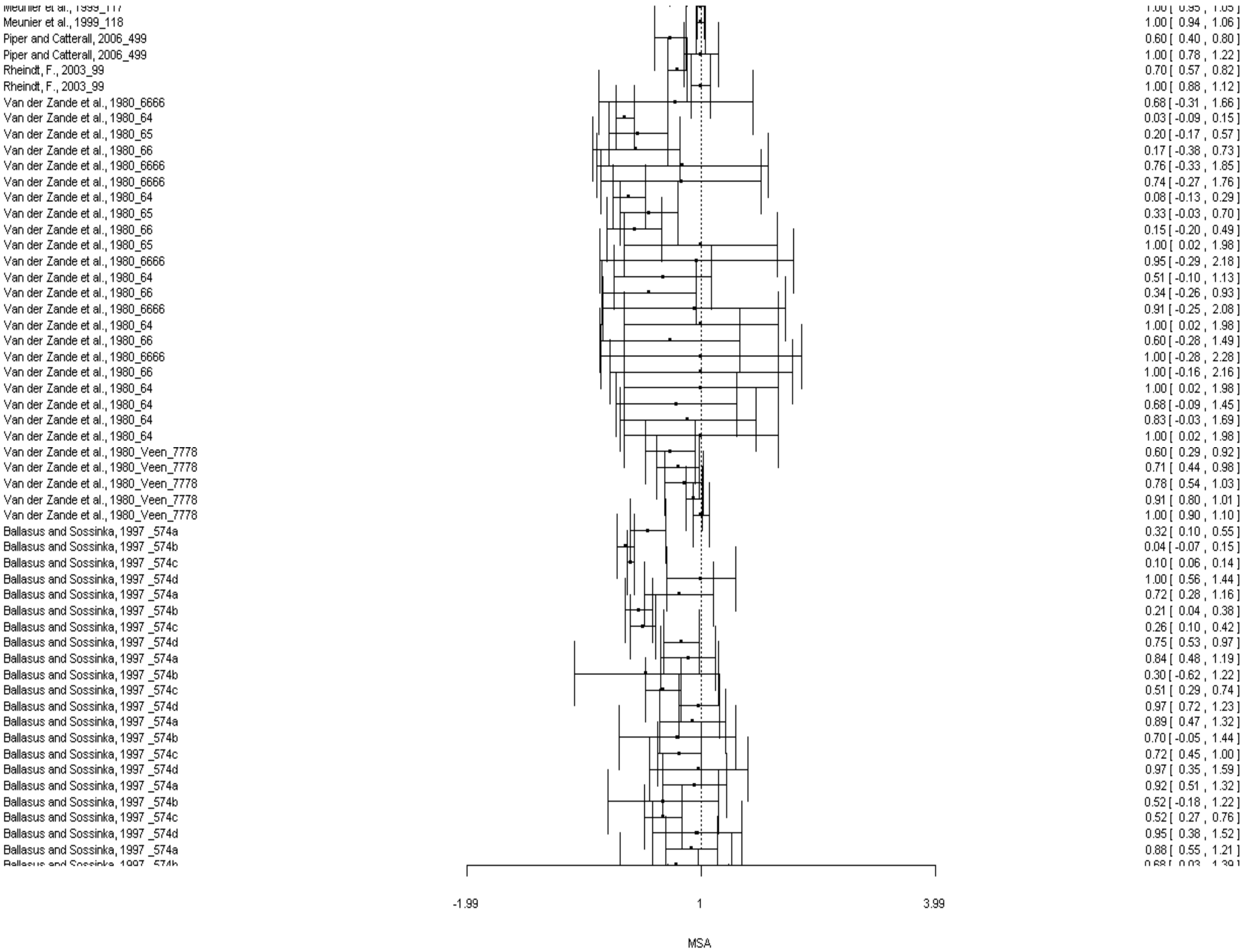
b) Second part of the forest plot for the meta-analysis for all distances.



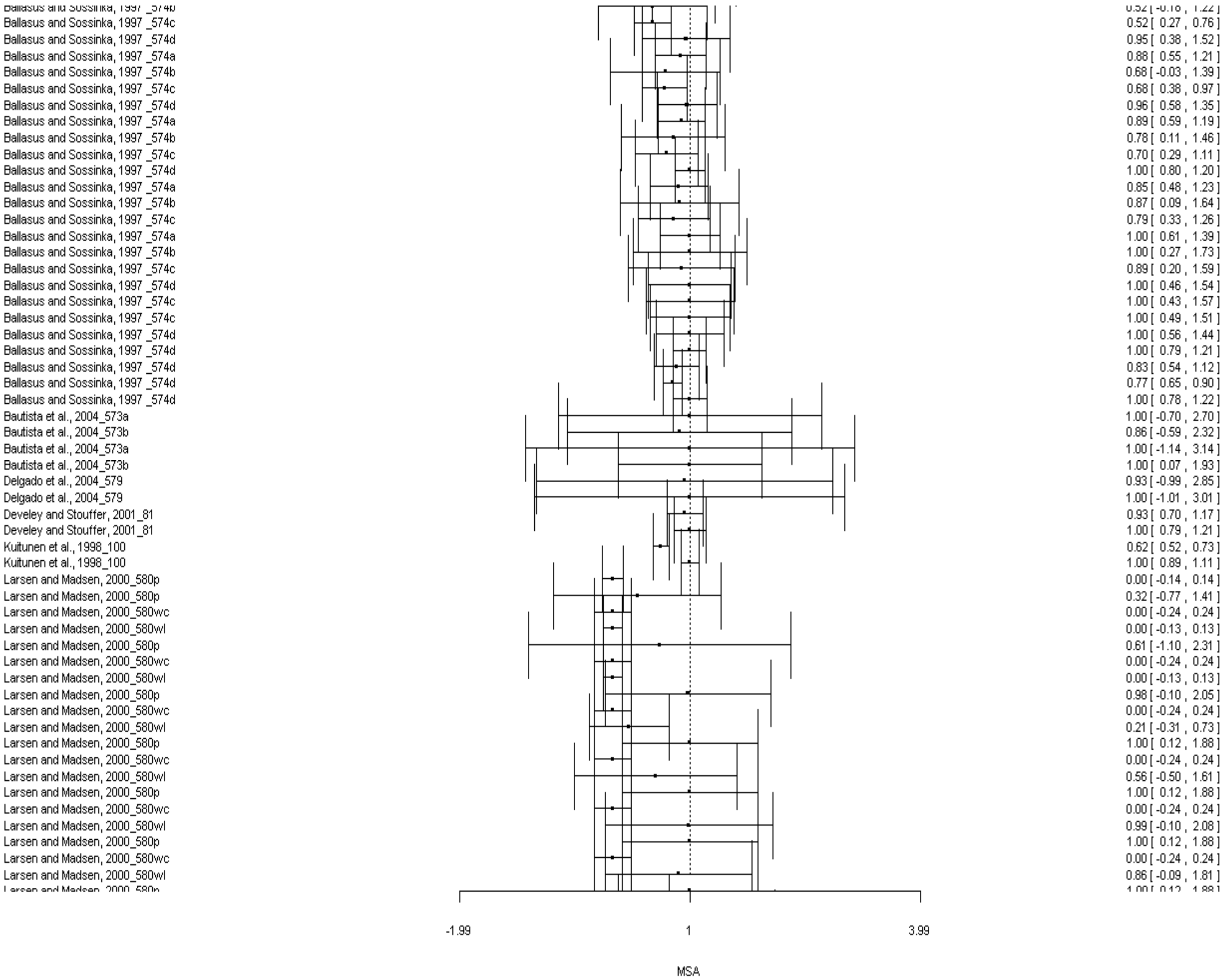
c) Third part of the forest plot for the meta-analysis for all distances.



d) Fourth part of the forest plot for the meta-analysis for all distances.



e) Fifth part of the forest plot for the meta-analysis for all distances.



f) Sixth part of the forest plot for the meta-analysis for all distances.

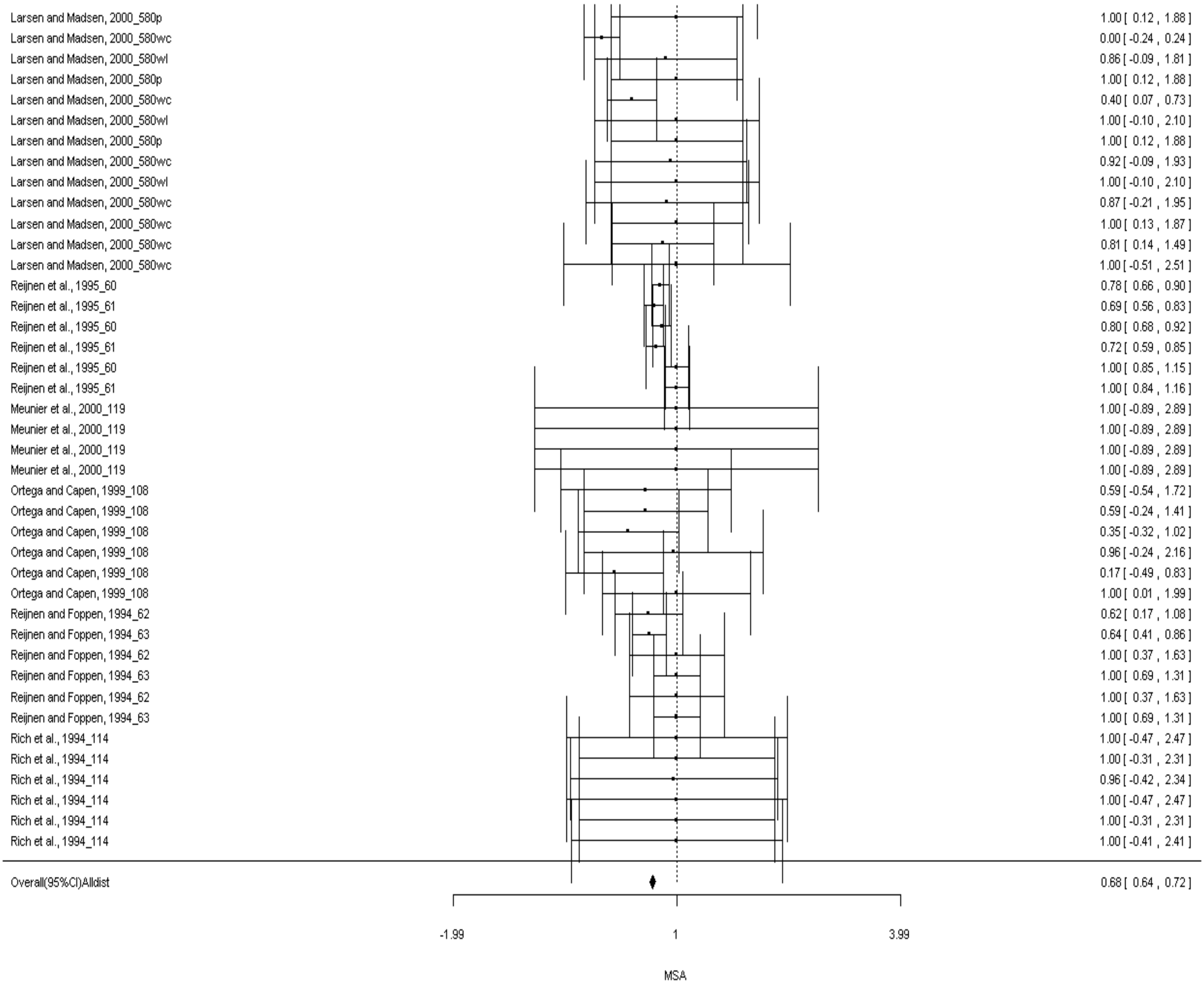


Figure 1. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at all distances (0-2580 m). The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals. Note: The plot is divided in several parts so that it can be visualized.

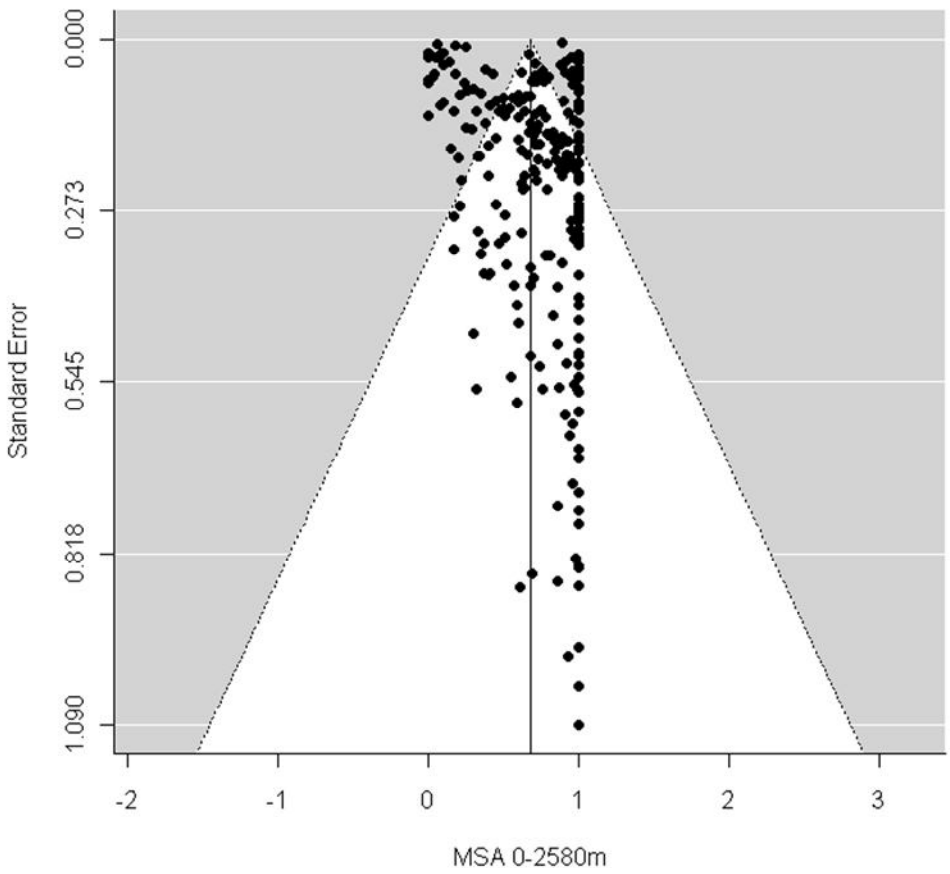


Figure 2. Funnel plot of the meta-analysis of bird species abundance at all distances (0-2580 m) from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

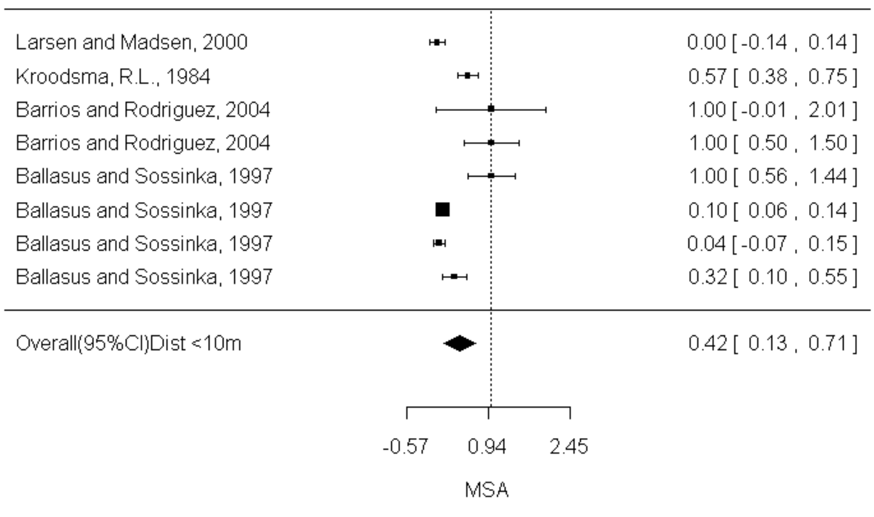


Figure 3. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval < 10 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

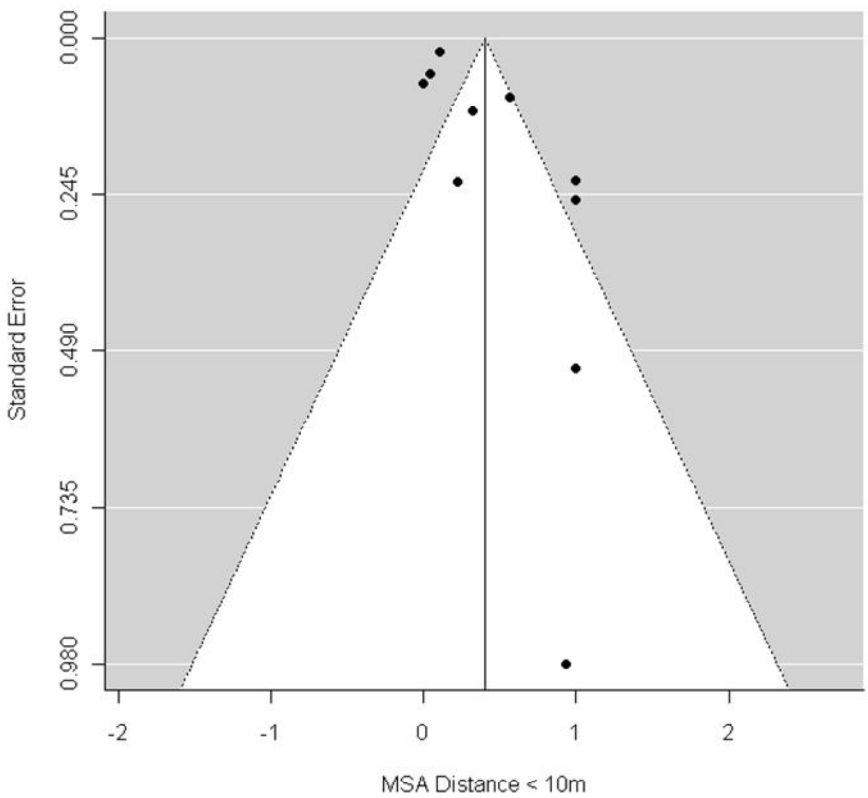


Figure 4. Funnel plot of the meta-analysis of bird species abundance at the distance interval < 10 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

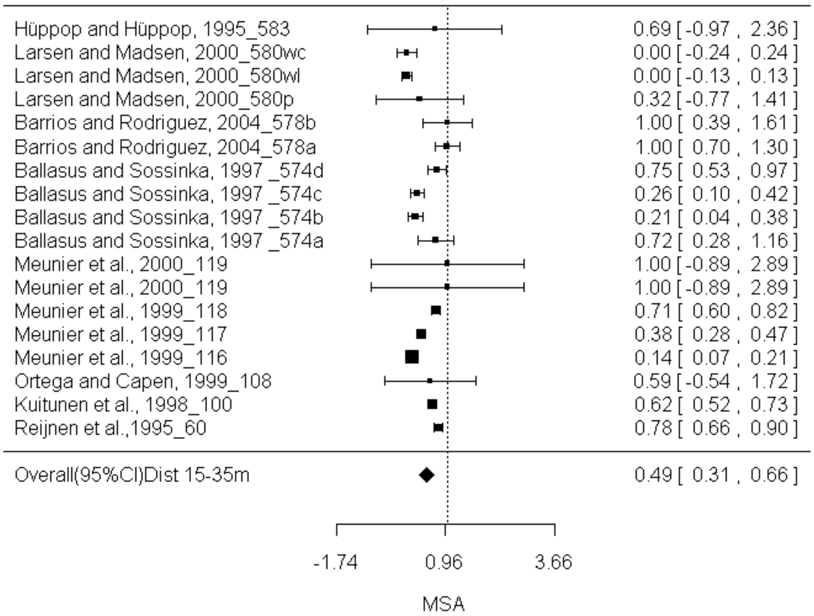


Figure 5. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 15-35 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

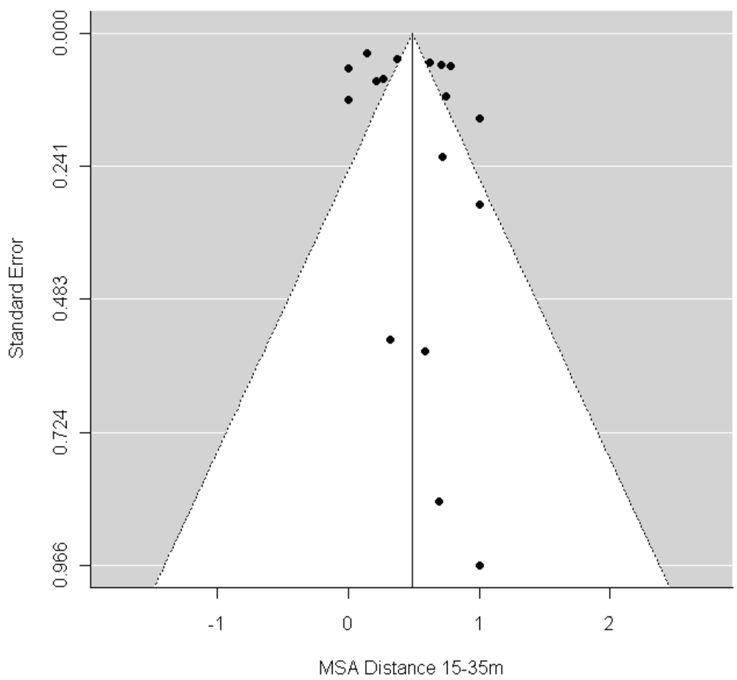


Figure 6. Funnel plot of the meta-analysis of bird species abundance at the distance interval 15-35 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

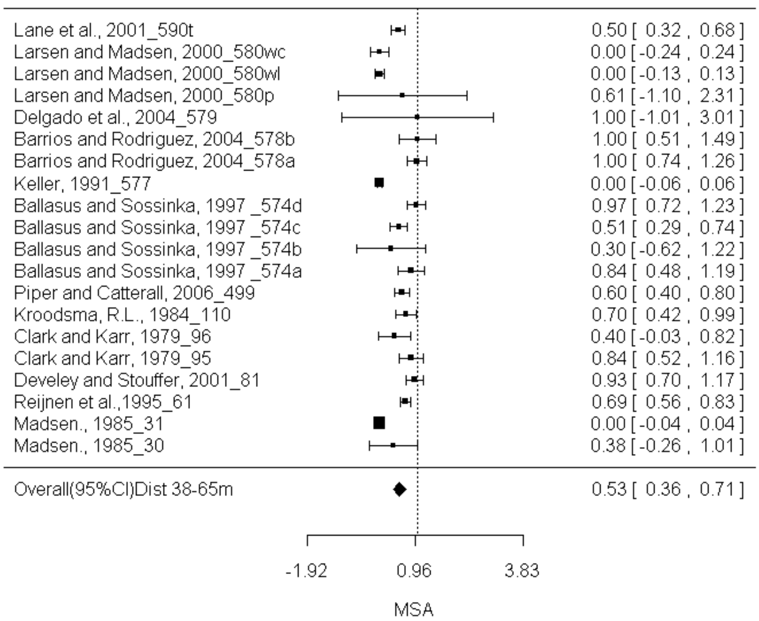


Figure 7. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 38-65 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

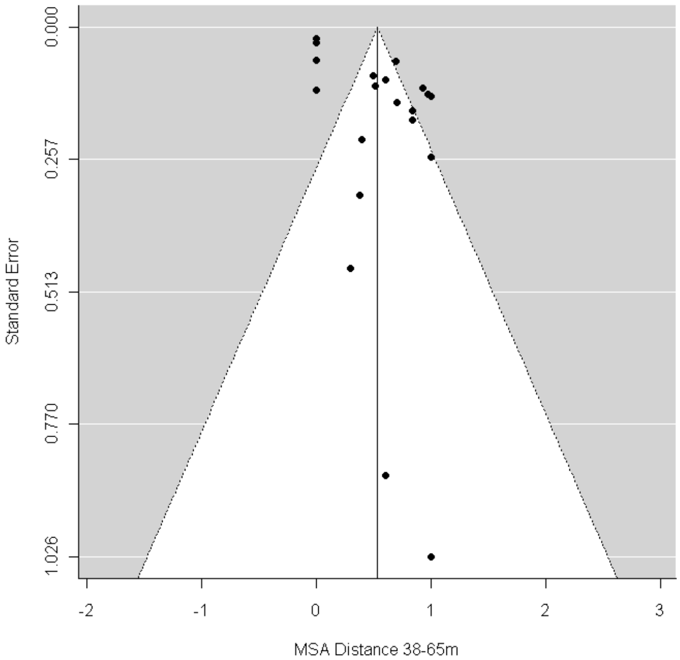


Figure 8. Funnel plot of the meta-analysis of bird species abundance at the distance interval 38-65 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

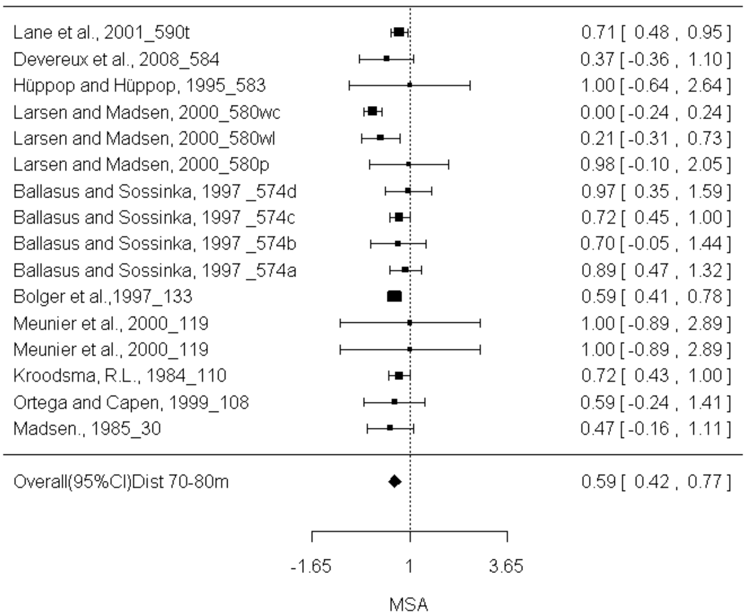


Figure 9. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 70-80 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

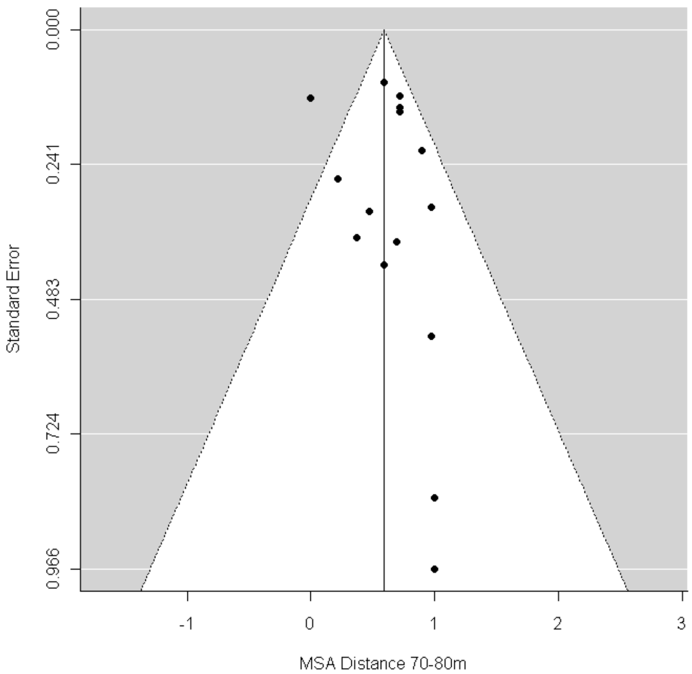


Figure 10. Funnel plot of the meta-analysis of bird species abundance at the distance interval 70-80 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

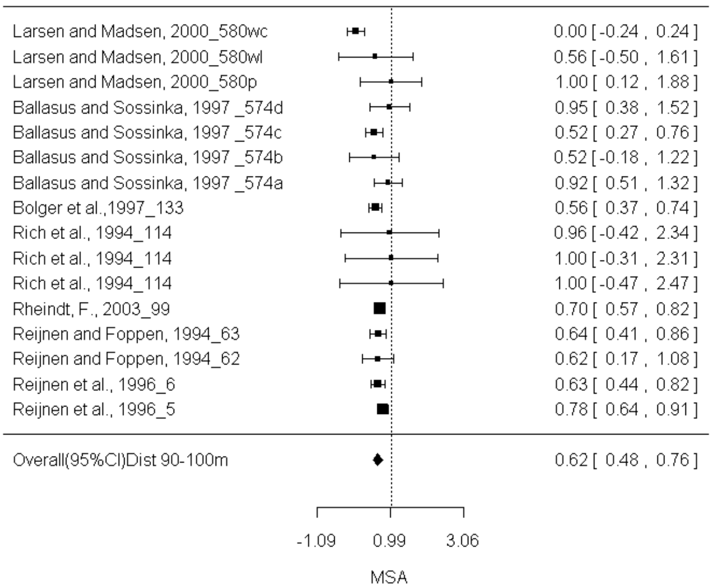


Figure 11. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 90-100 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

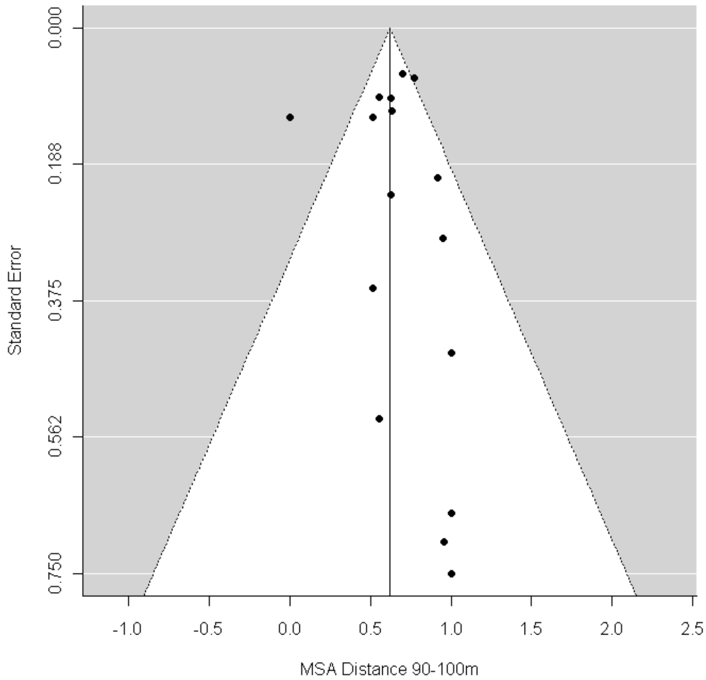


Figure 12. Funnel plot of the meta-analysis of bird species abundance at the distance interval 90-100 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

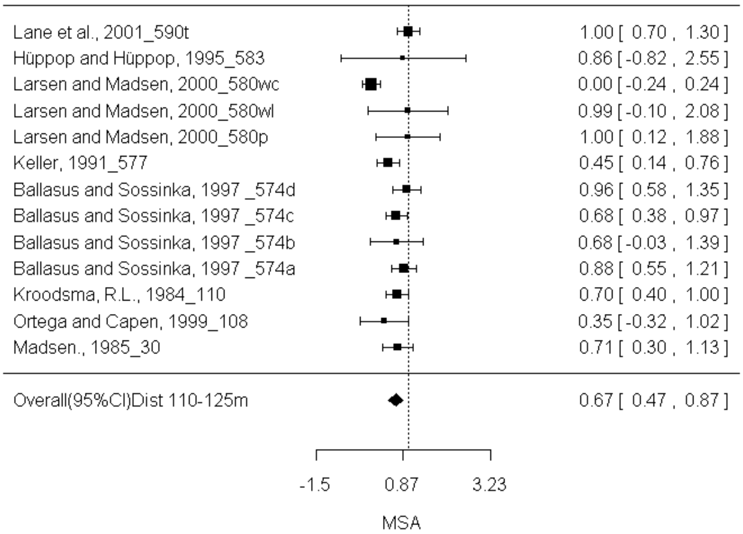


Figure 13. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 110-125 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

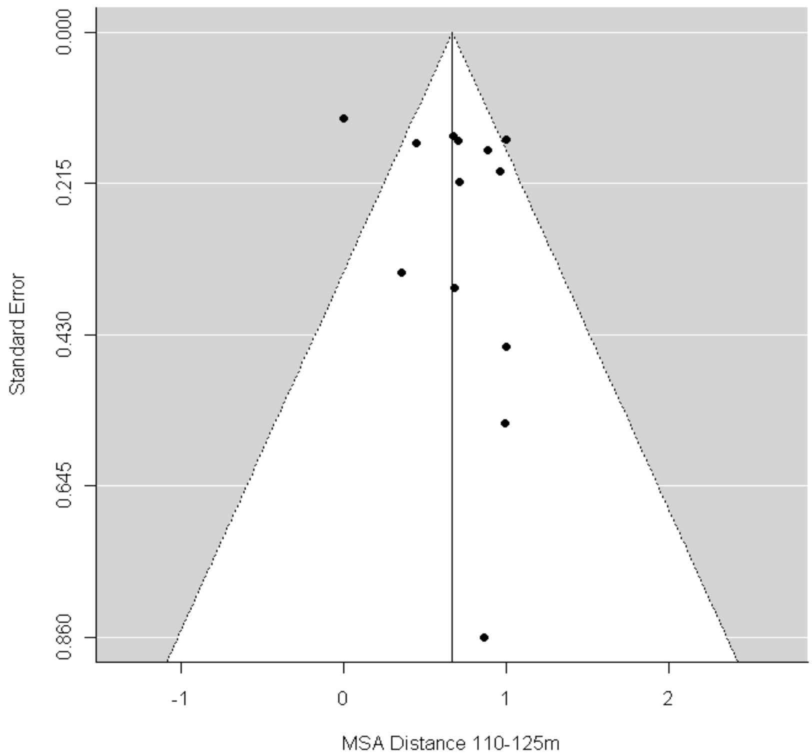


Figure 14. Funnel plot of the meta-analysis of bird species abundance at the distance interval 110-125 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

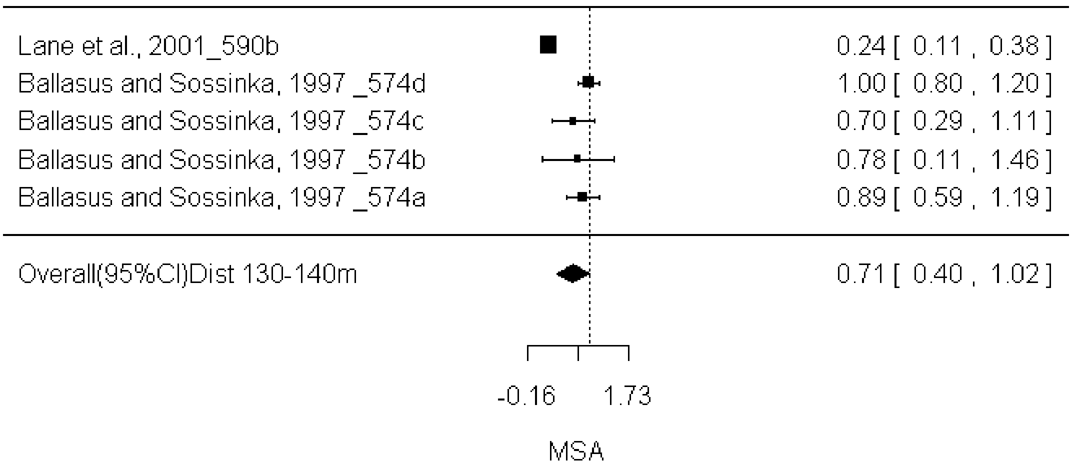


Figure 15. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 130-140 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

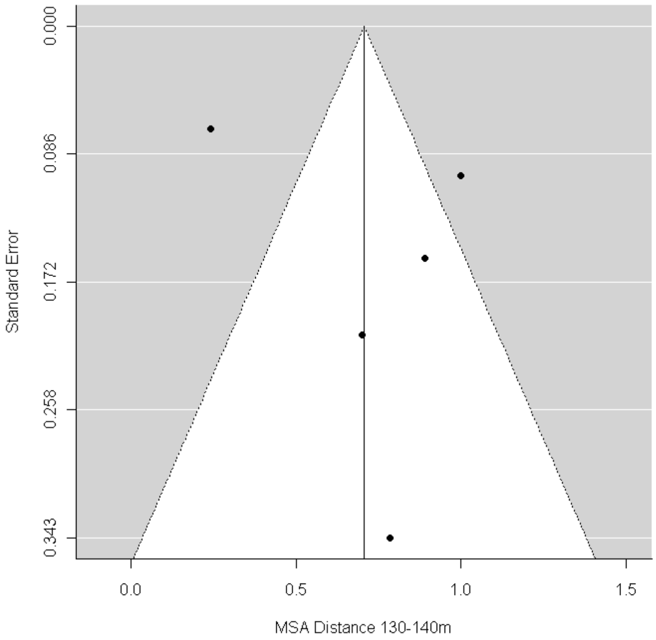


Figure 16. Funnel plot of the meta-analysis of bird species abundance at the distance interval 130-140 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

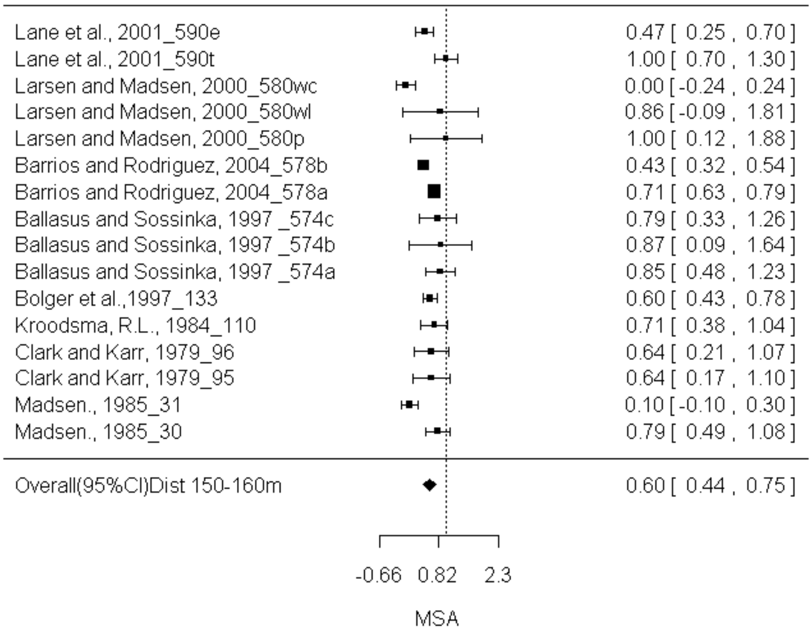


Figure 17. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 150-160 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

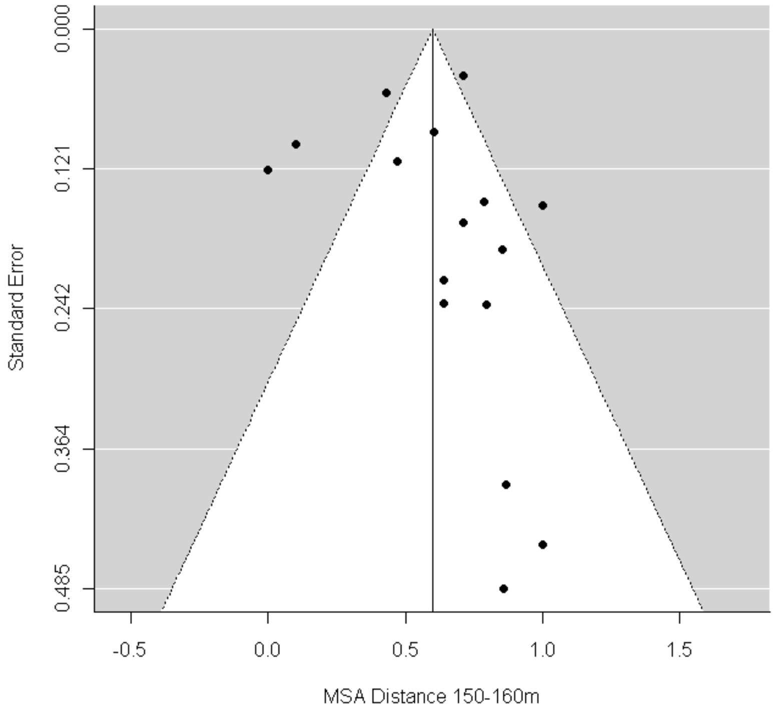


Figure 18. Funnel plot of the meta-analysis of bird species abundance at the distance interval 150-160 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

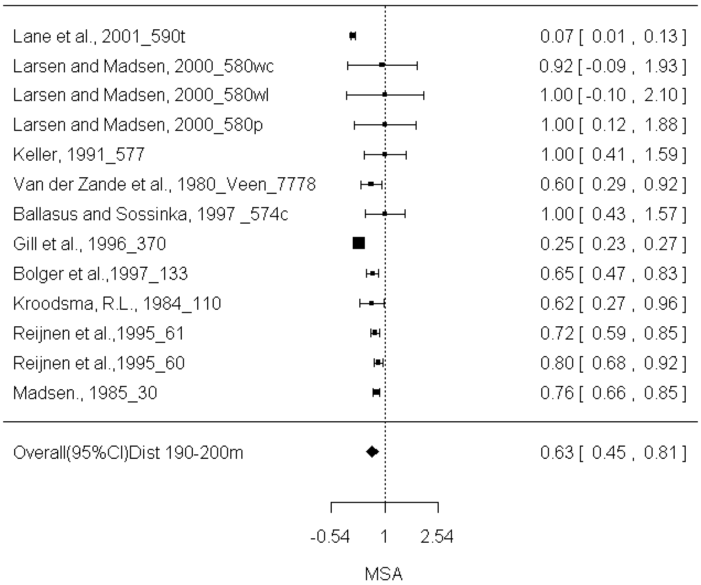


Figure 19. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 190-200 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

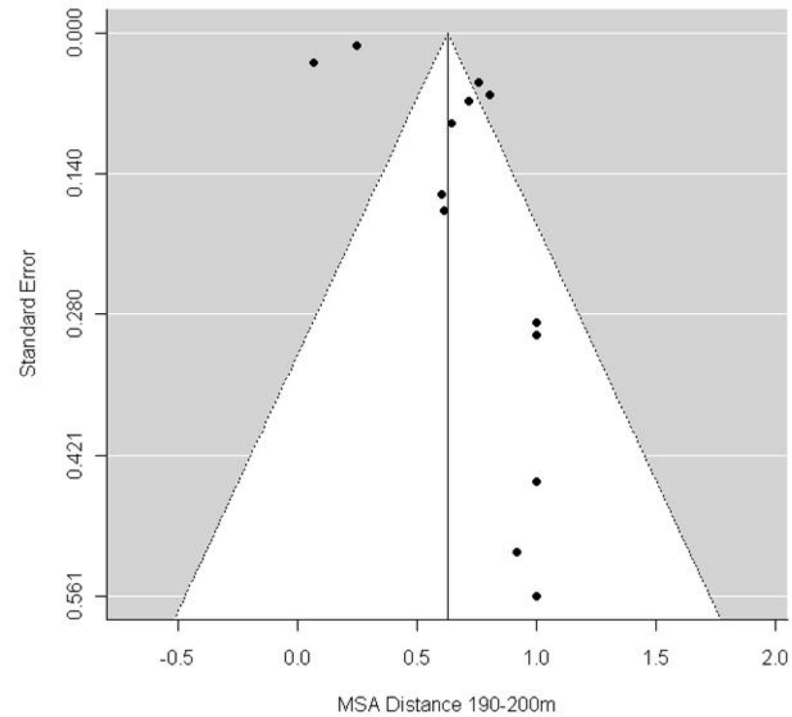


Figure 20. Funnel plot of the meta-analysis of bird species abundance at the distance interval 190-200 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

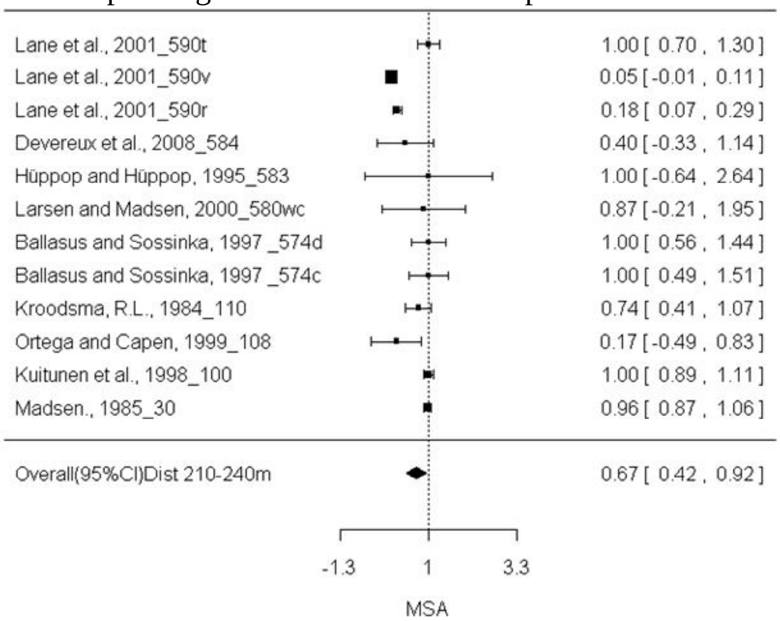


Figure 21. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 210-240 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

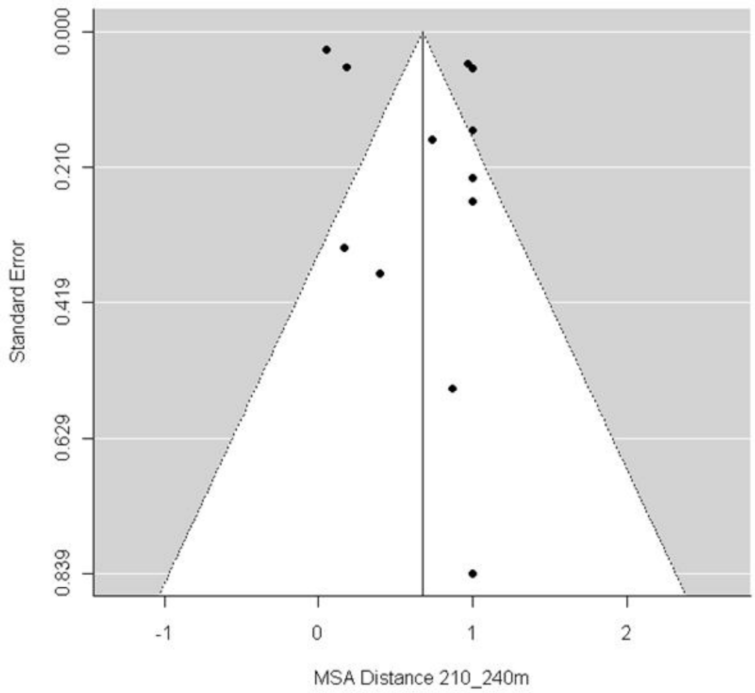


Figure 22. Funnel plot of the meta-analysis of bird species abundance at the distance interval 210-240 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

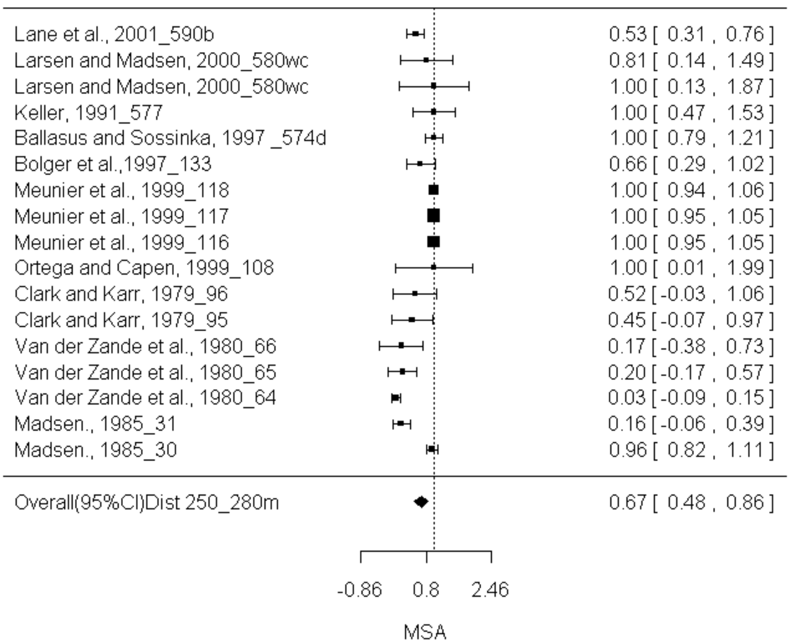


Figure 23. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 250-280 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

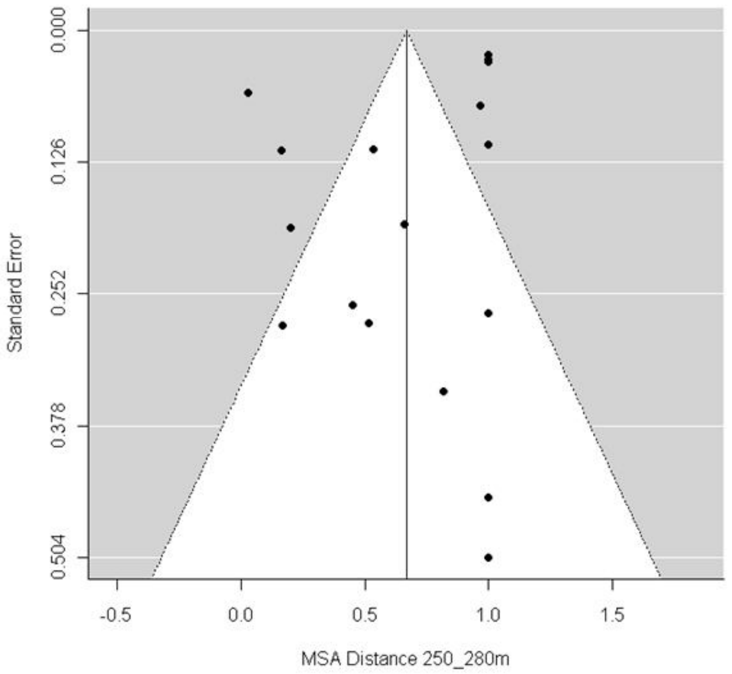


Figure 24. Funnel plot of the meta-analysis of bird species abundance at the distance interval 250-280 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

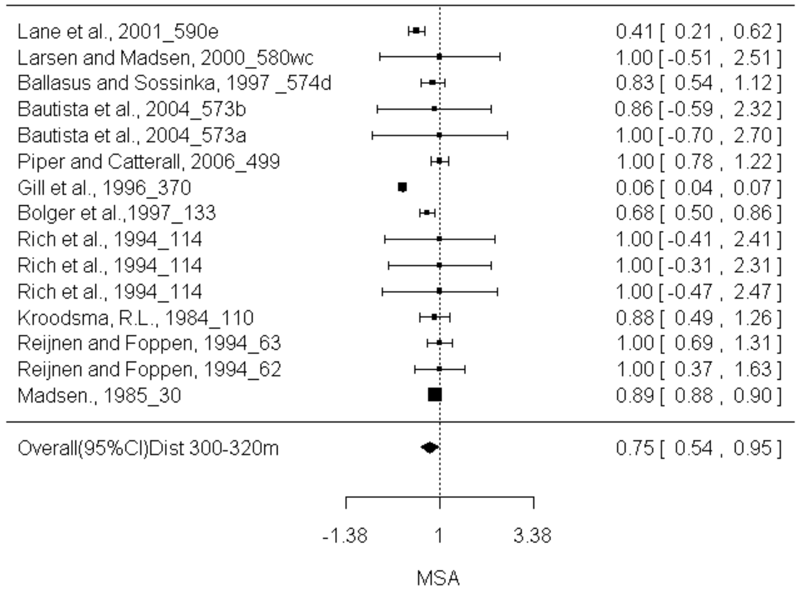


Figure 25. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 300-320 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

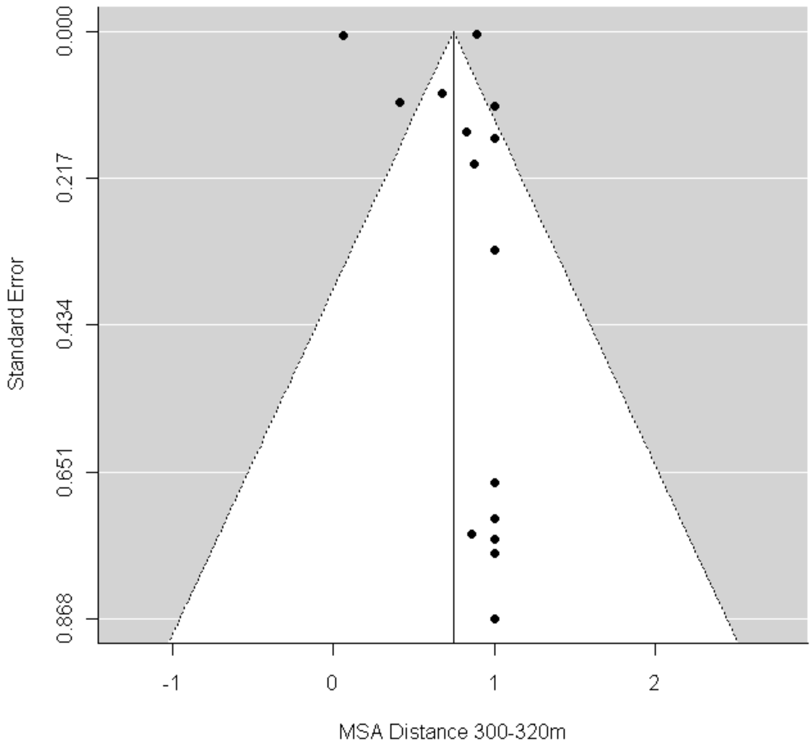


Figure 26. Funnel plot of the meta-analysis of bird species abundance at the distance interval 300-320 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

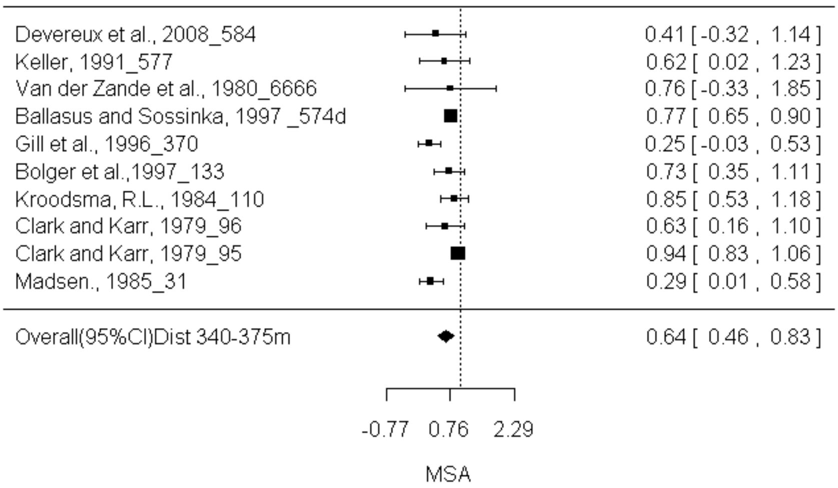


Figure 27. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 340-375 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

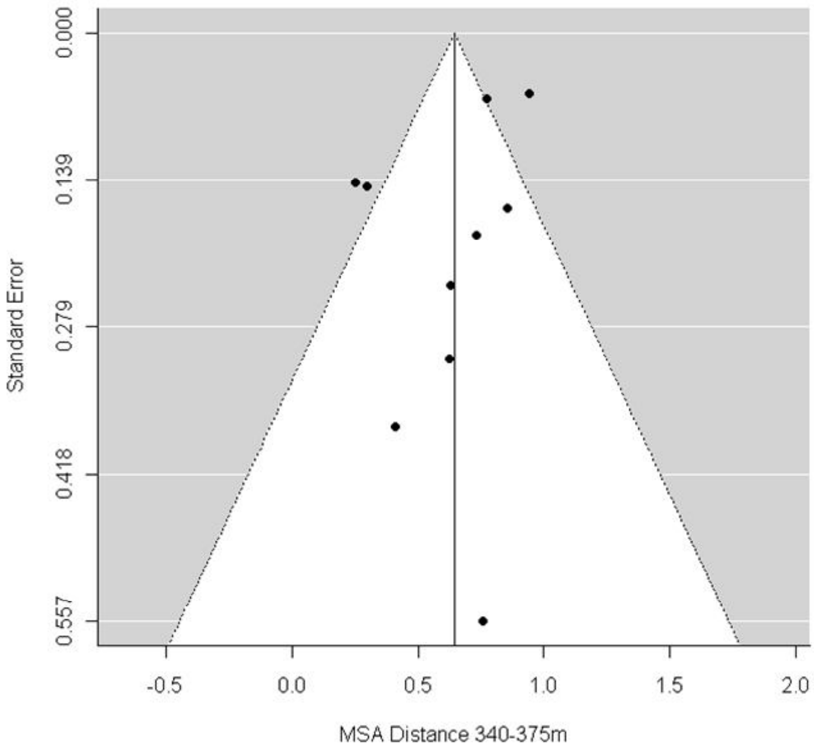


Figure 28. Funnel plot of the meta-analysis of bird species abundance at the distance interval 340-375 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

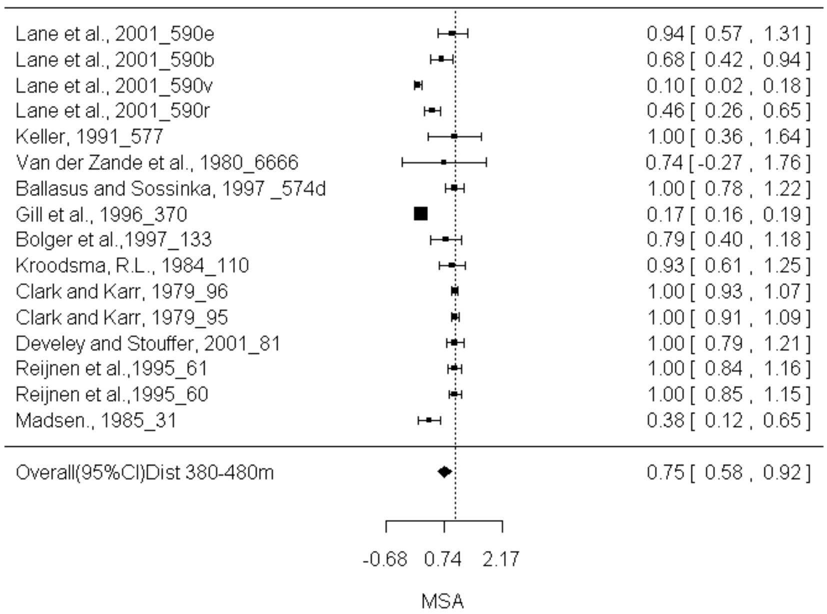


Figure 29. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 380-480 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

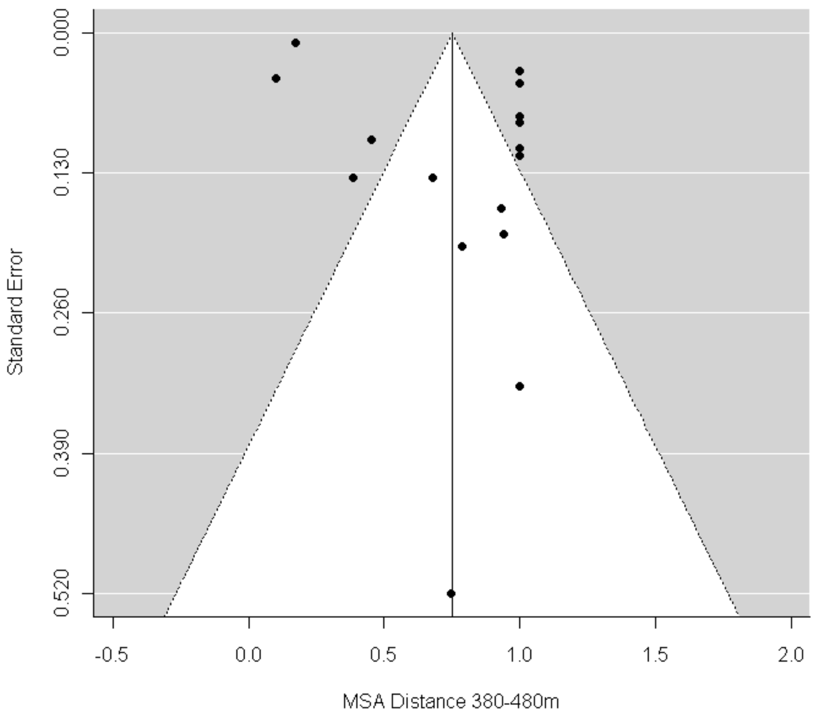


Figure 30. Funnel plot of the meta-analysis of bird species abundance at the distance interval 380-480 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

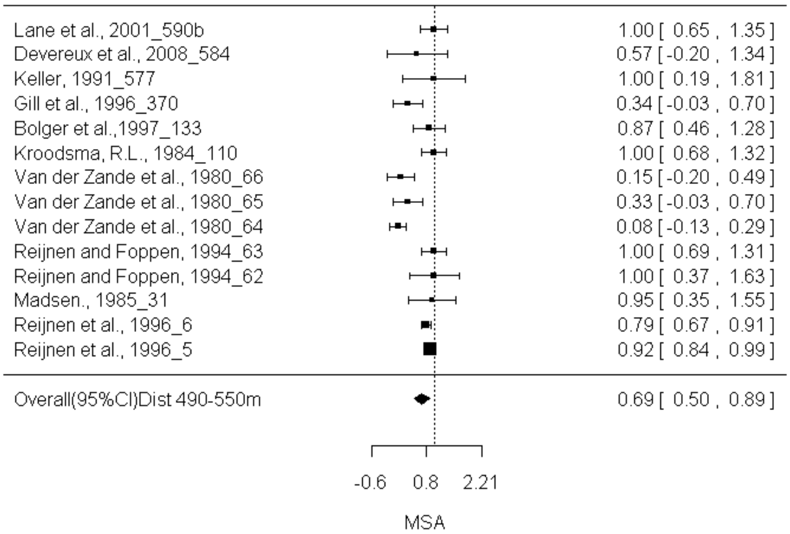


Figure 31. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 490-550 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

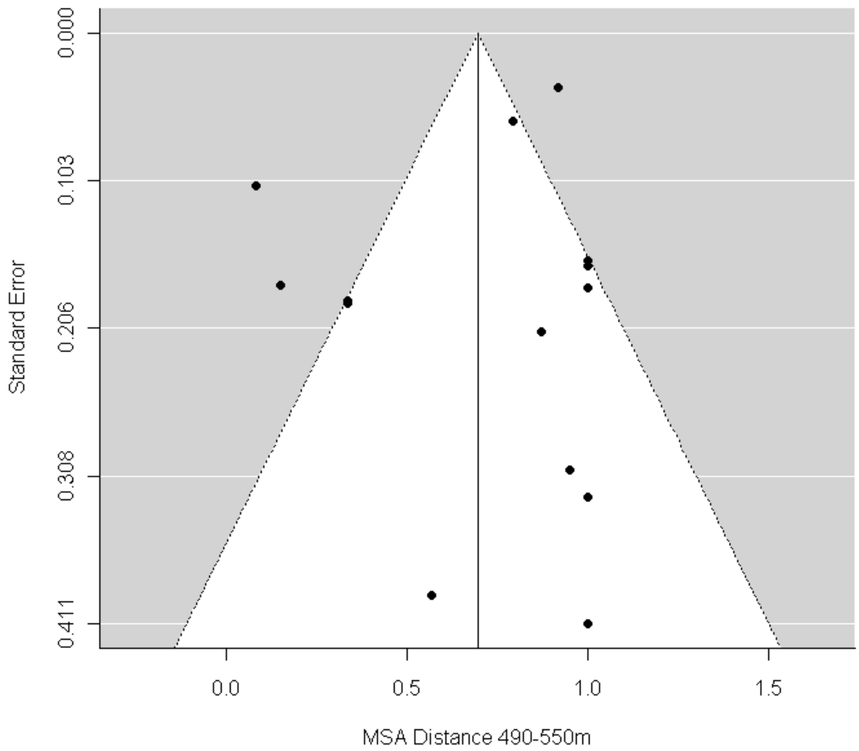


Figure 32. Funnel plot of the meta-analysis of bird species abundance at the distance interval 490-550 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

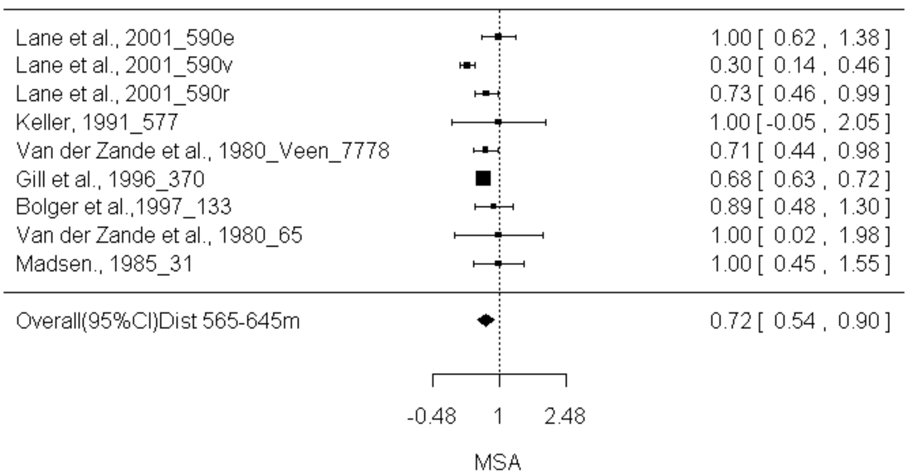


Figure 33. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 565-645 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

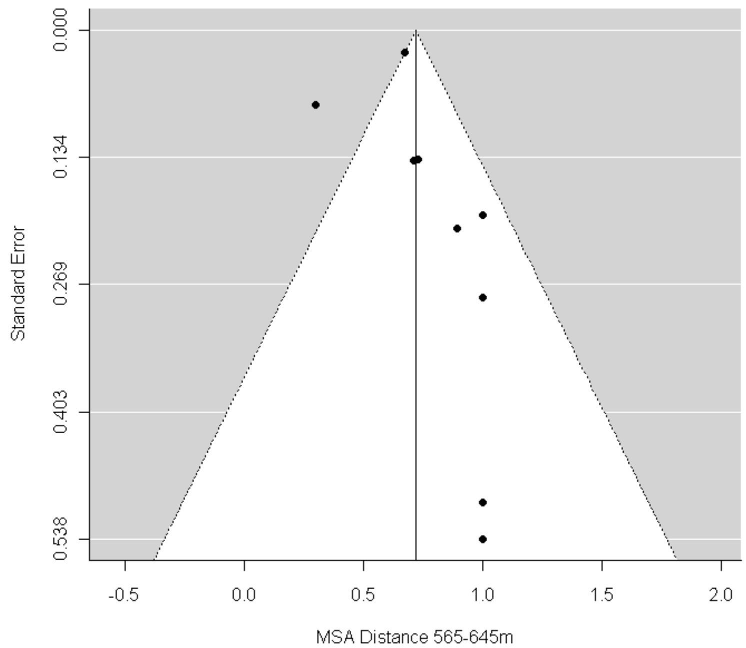


Figure 34. Funnel plot of the meta-analysis of bird species abundance at the distance interval 565-645 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

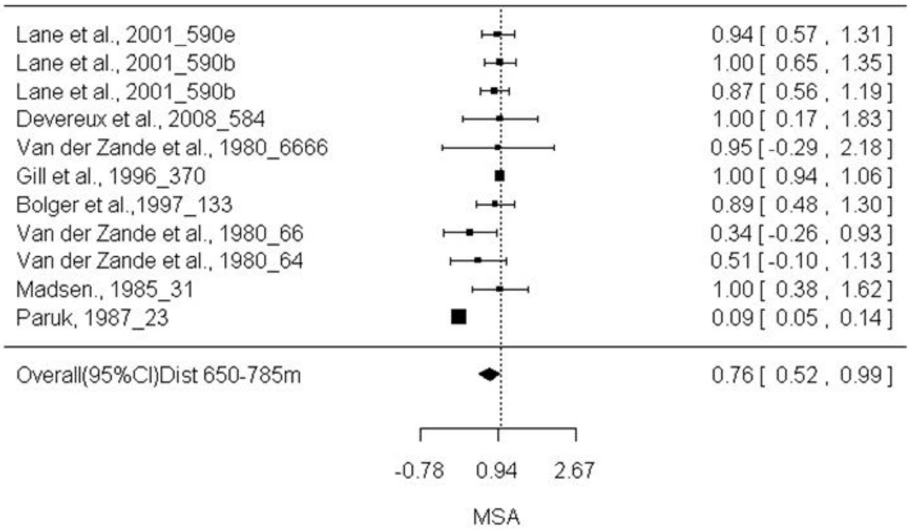


Figure 35. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 650-785 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

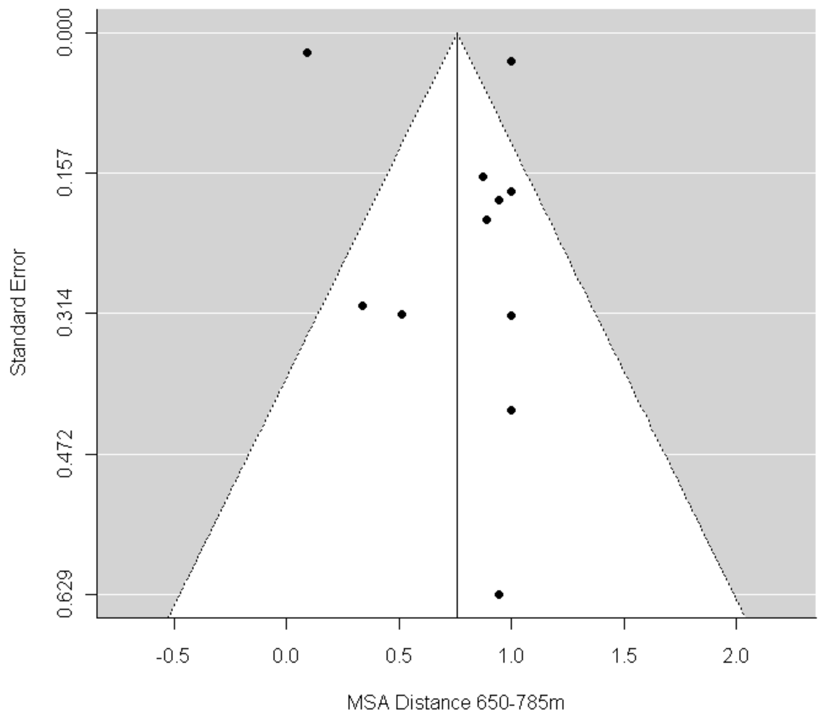


Figure 36. Funnel plot of the meta-analysis of bird species abundance at the distance interval 650-785 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

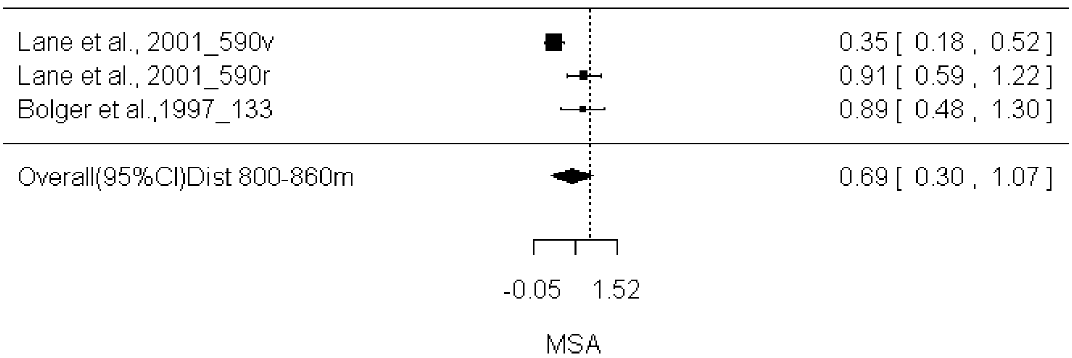


Figure 37. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 800-860 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

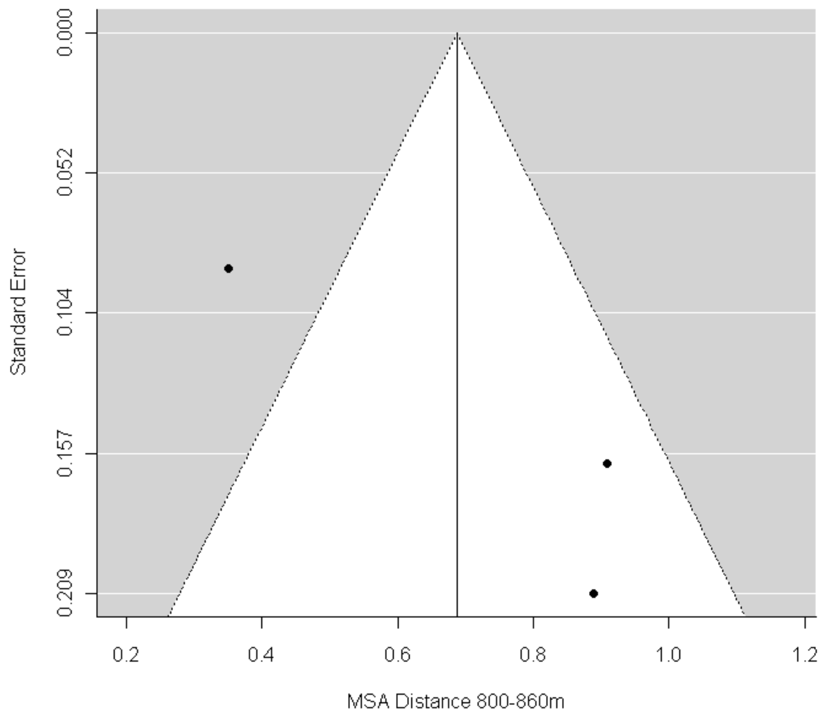


Figure 38. Funnel plot of the meta-analysis of bird species abundance at the distance interval 800-860 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

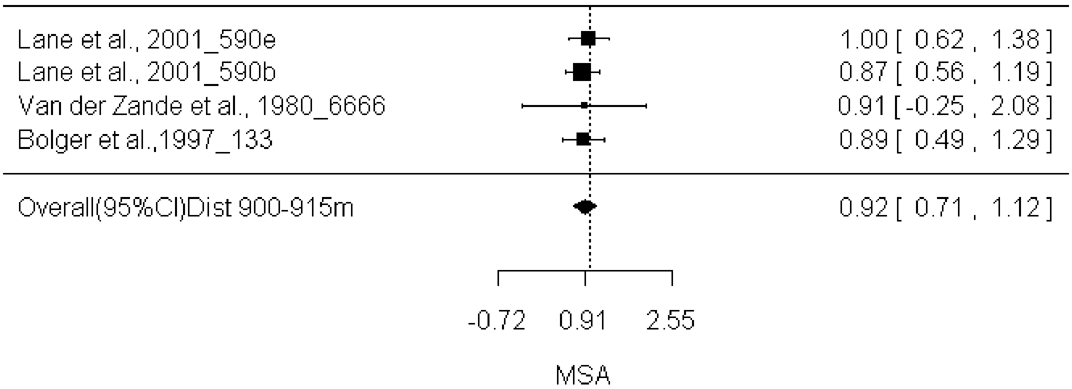


Figure 39. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 900-915 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

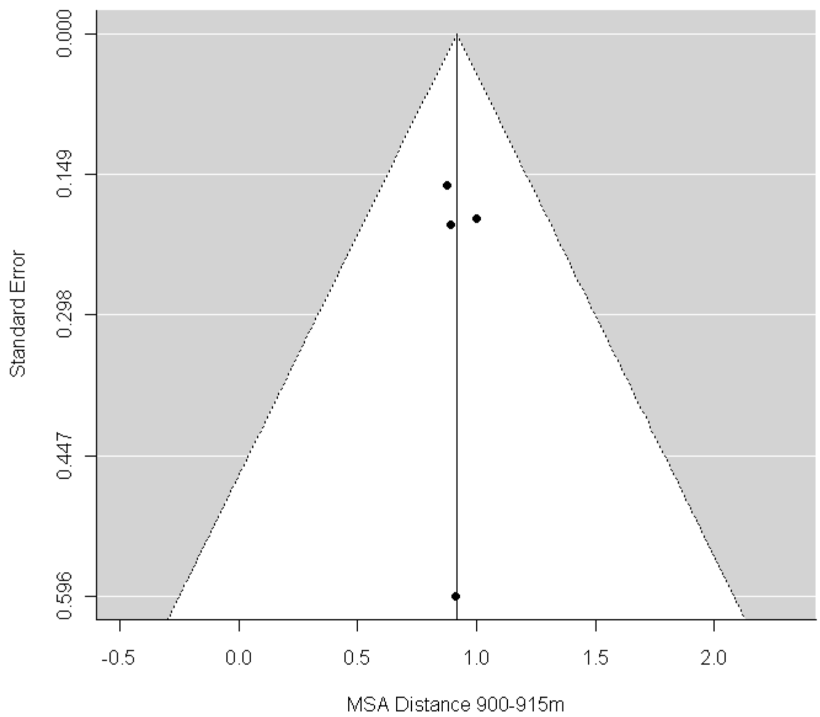


Figure 40. Funnel plot of the meta-analysis of bird species abundance at the distance interval 900-915 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

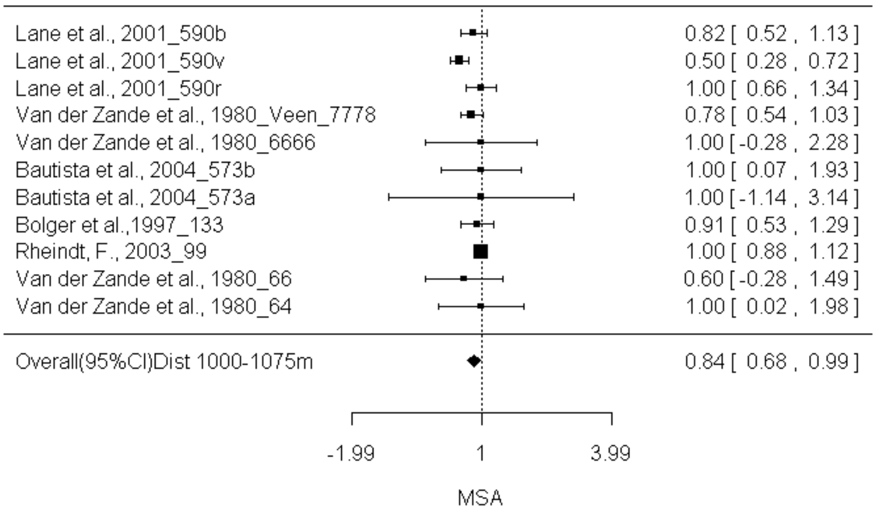


Figure 41. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 1000-1075 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

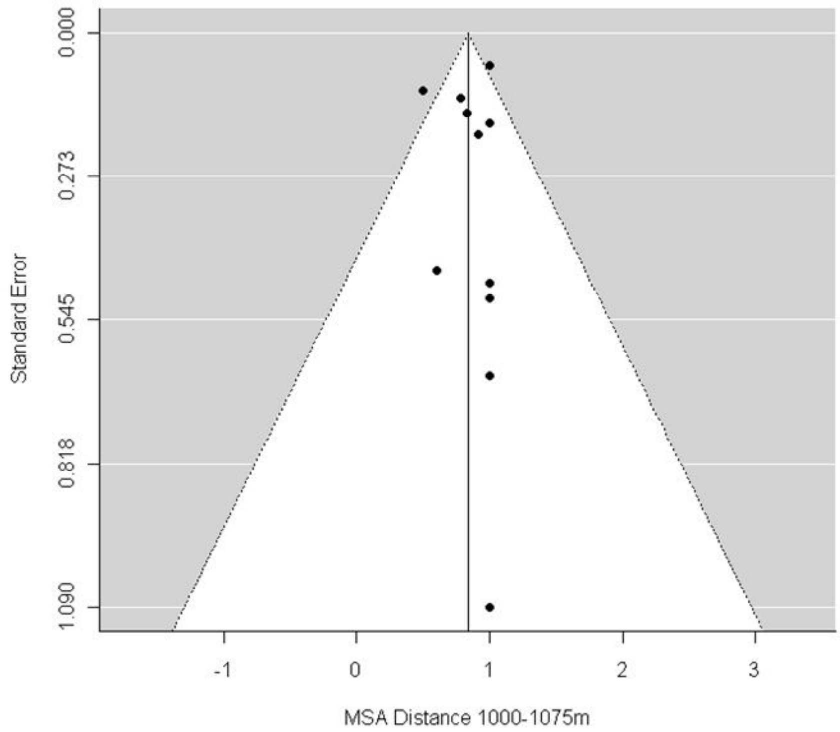


Figure 42. Funnel plot of the meta-analysis of bird species abundance at the distance interval 1000-1075 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

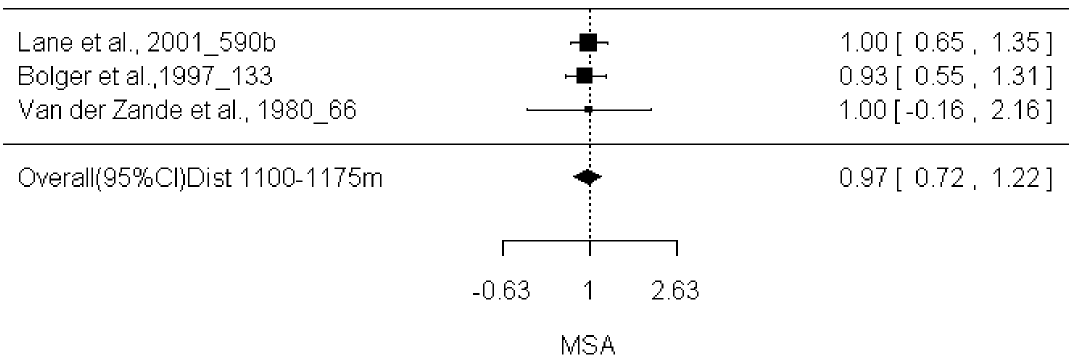


Figure 43. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 1100-1175 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

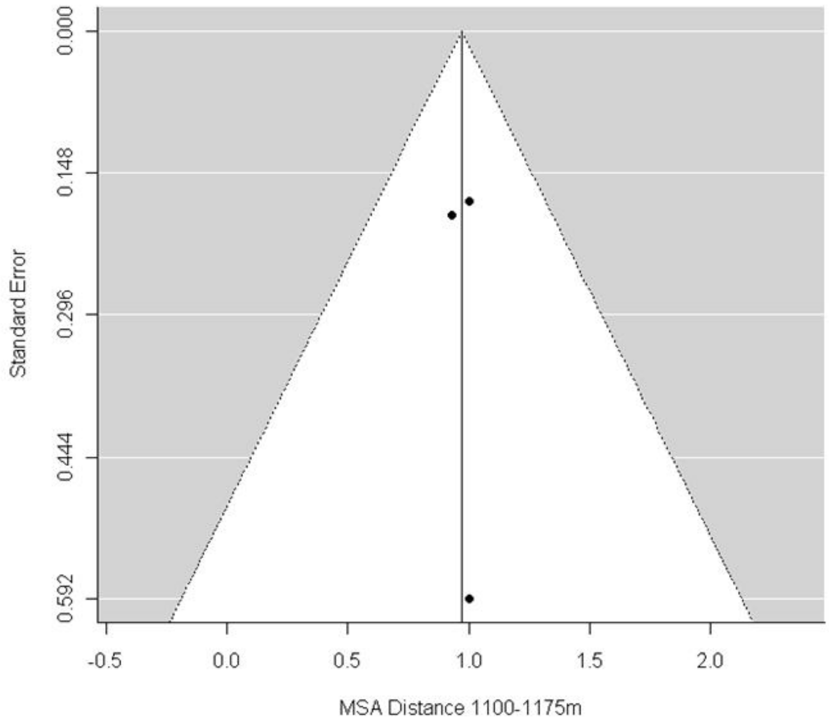


Figure 44. Funnel plot of the meta-analysis of bird species abundance at the distance interval 1100-1175 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

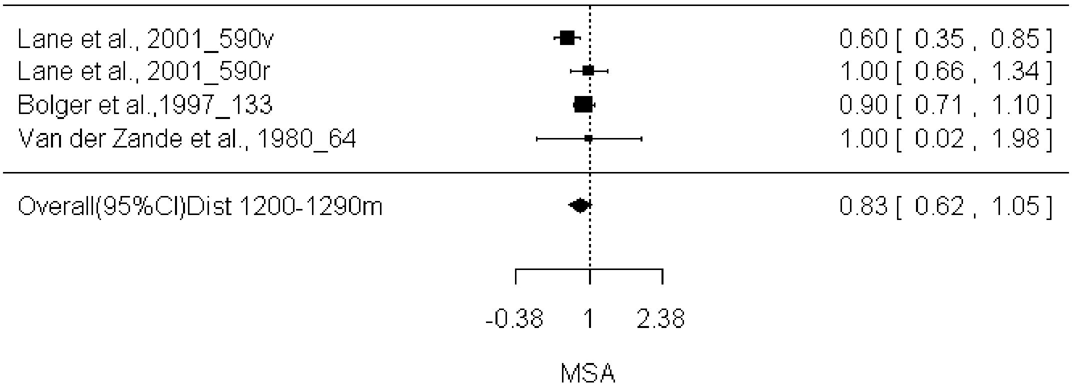


Figure 45. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 1200-1290 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

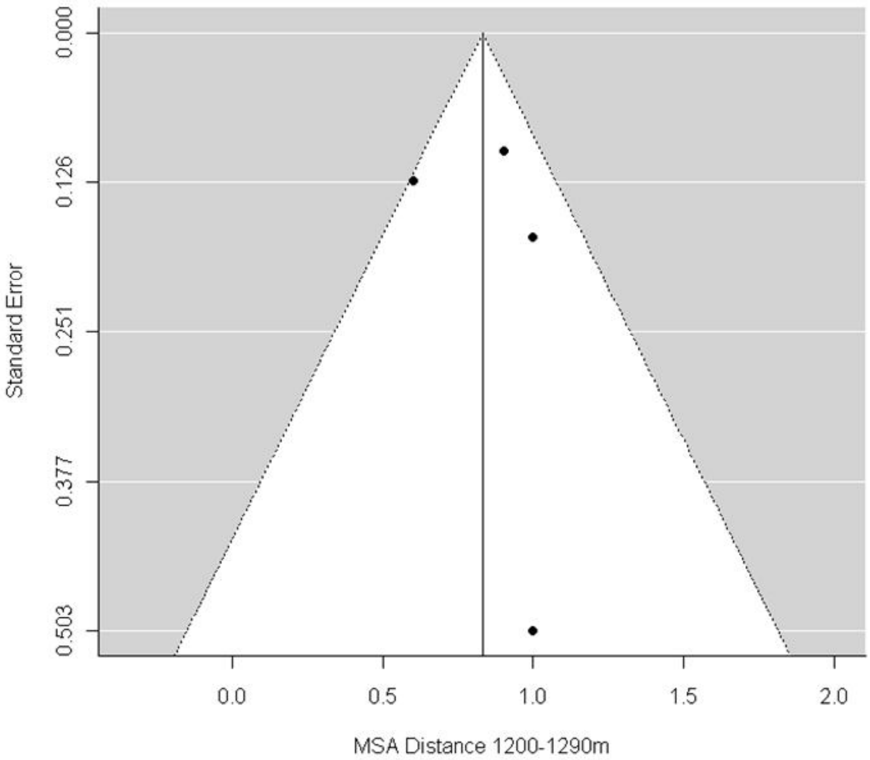


Figure 46. Funnel plot of the meta-analysis of bird species abundance at the distance interval 1200-1290 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

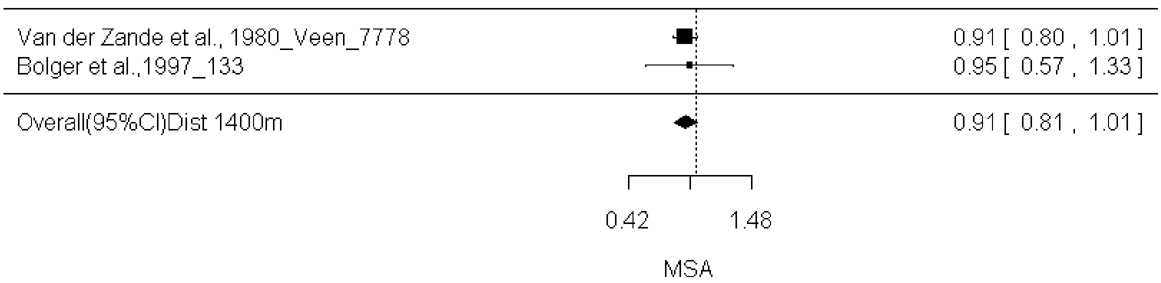


Figure 47. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 1400 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

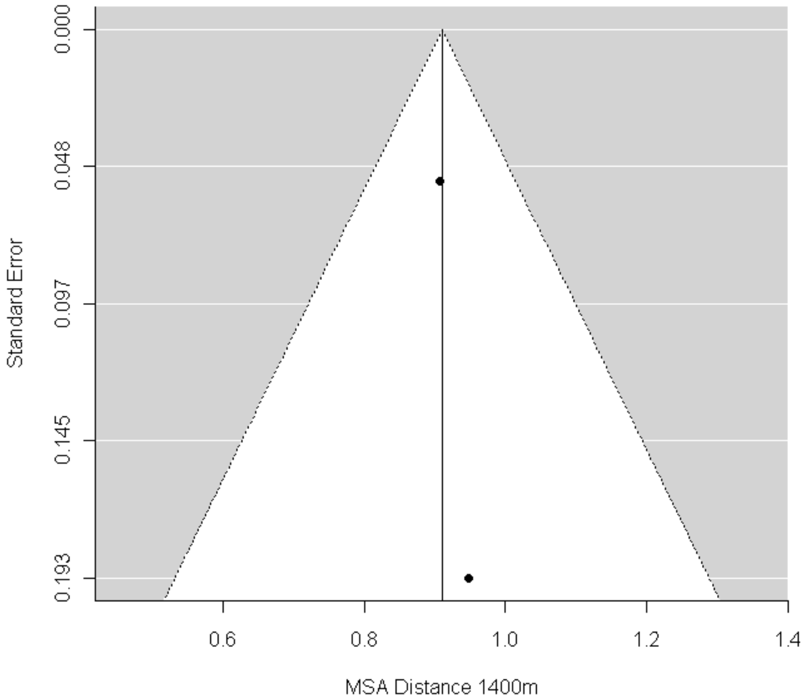


Figure 48. Funnel plot of the meta-analysis of bird species abundance at the distance interval 1400 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

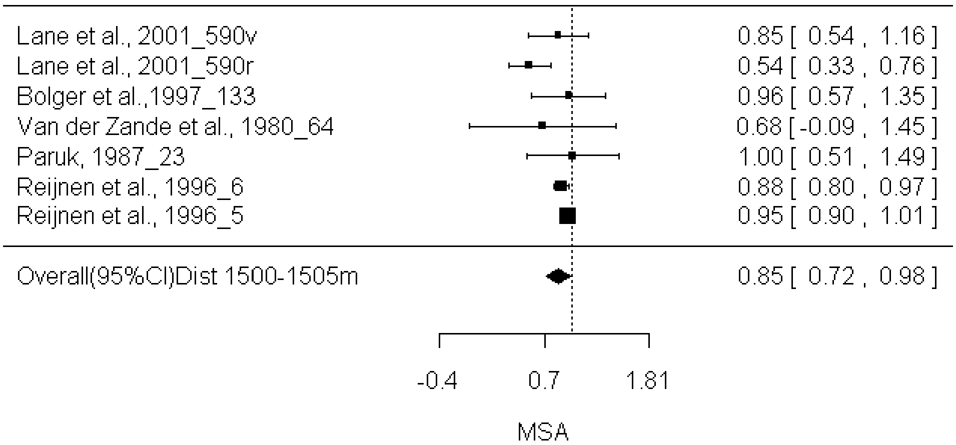


Figure 49. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 1500-1505 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

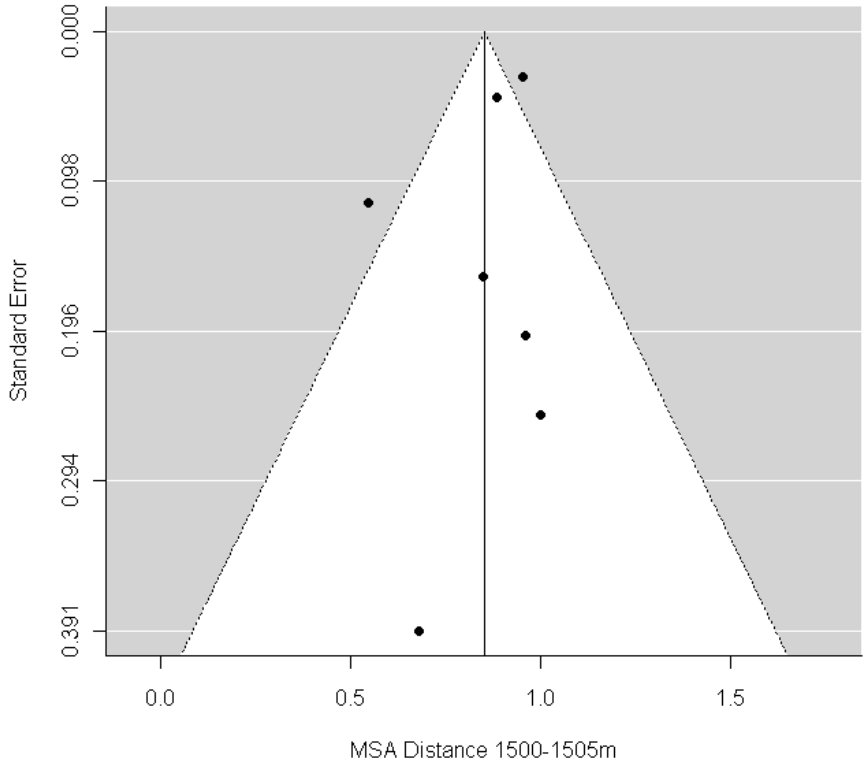


Figure 50. Funnel plot of the meta-analysis of bird species abundance at the distance interval 1500-1505 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

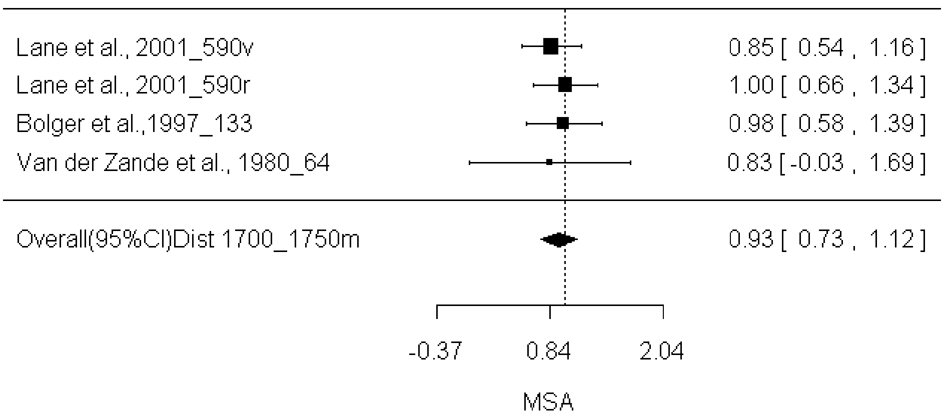


Figure 51. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 1700-1750 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

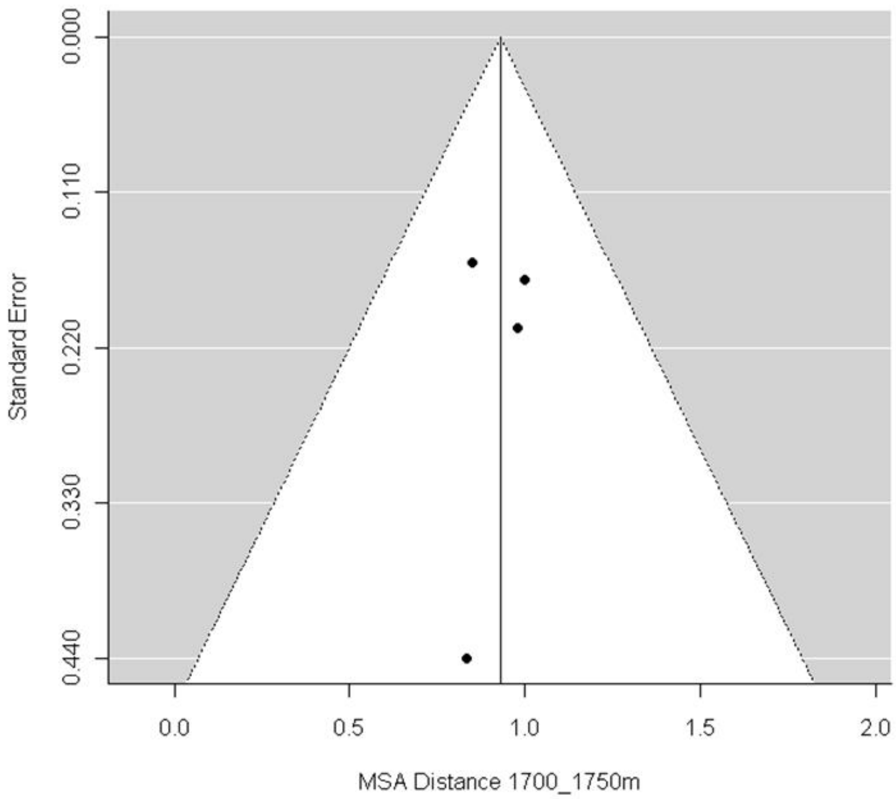


Figure 50. Funnel plot of the meta-analysis of bird species abundance at the distance interval 1700-1750 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

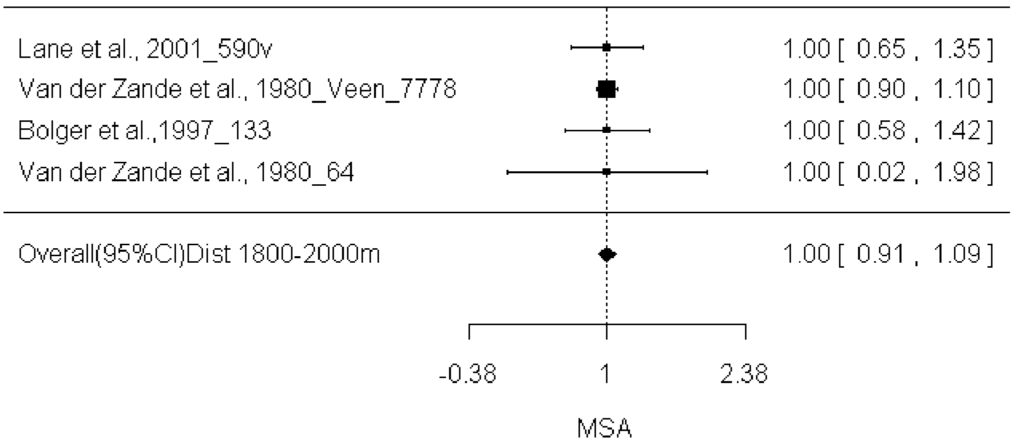


Figure 51. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on bird abundance at the distance interval 1800-2000 m. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

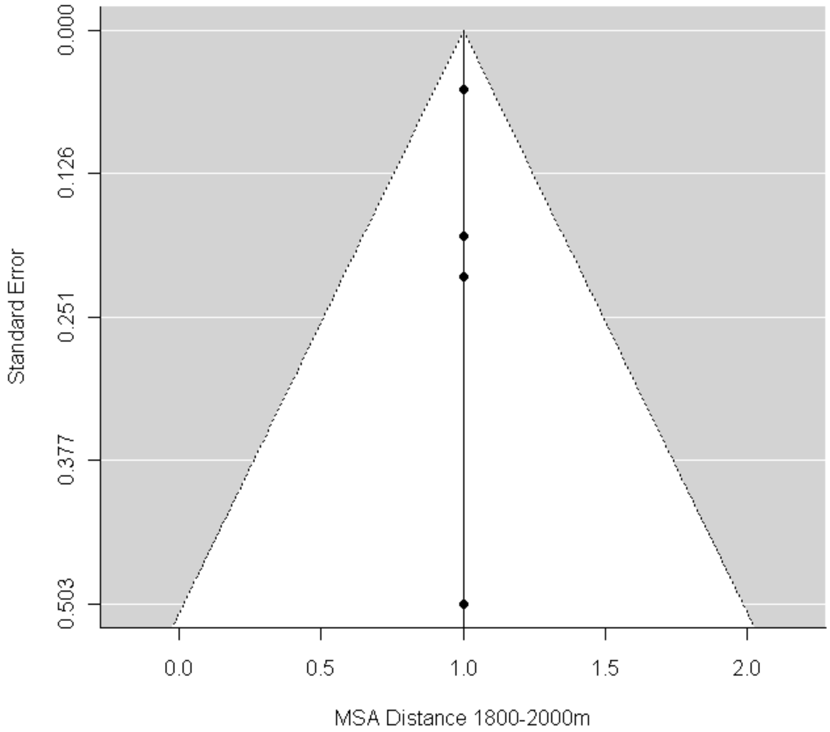
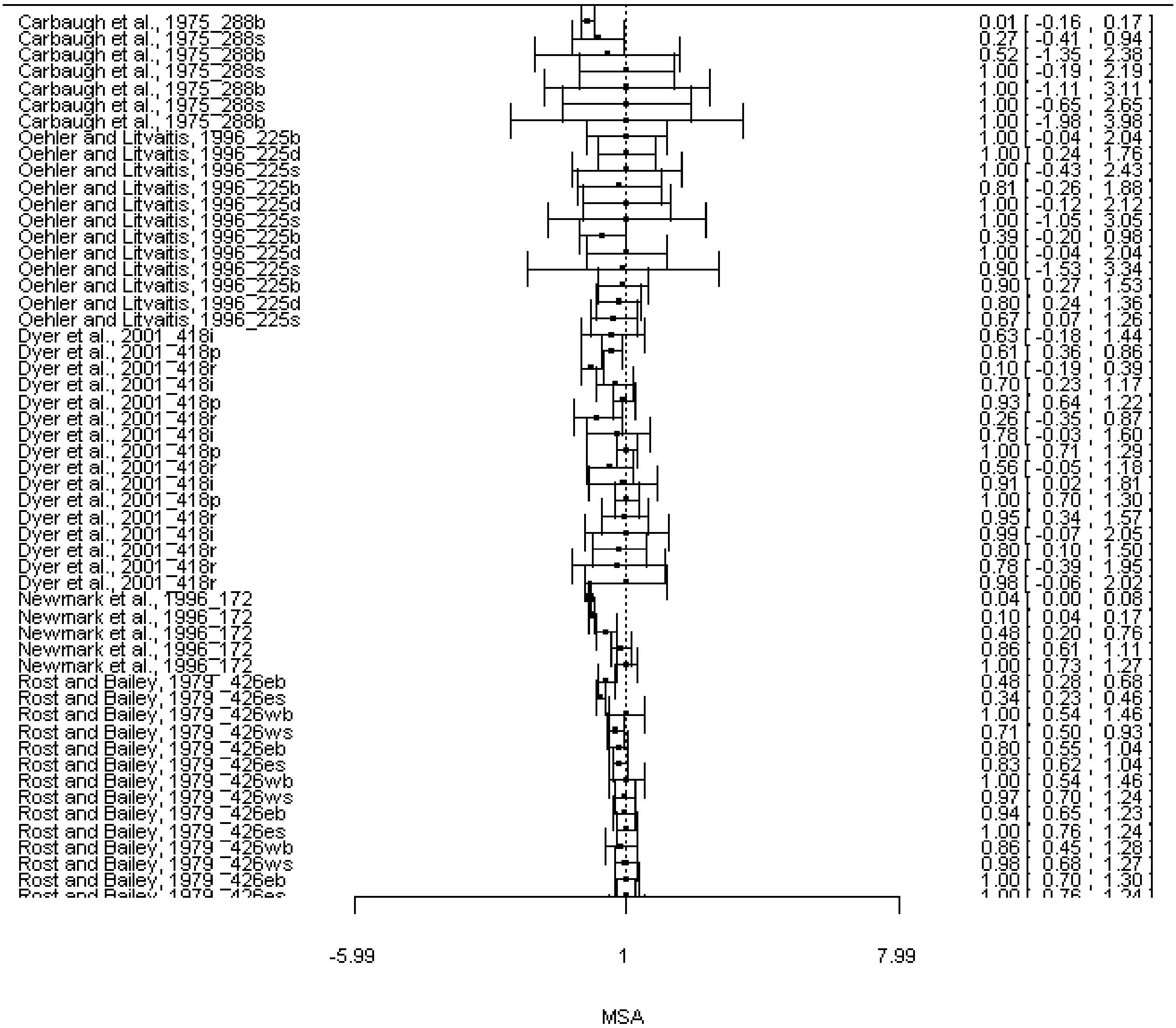


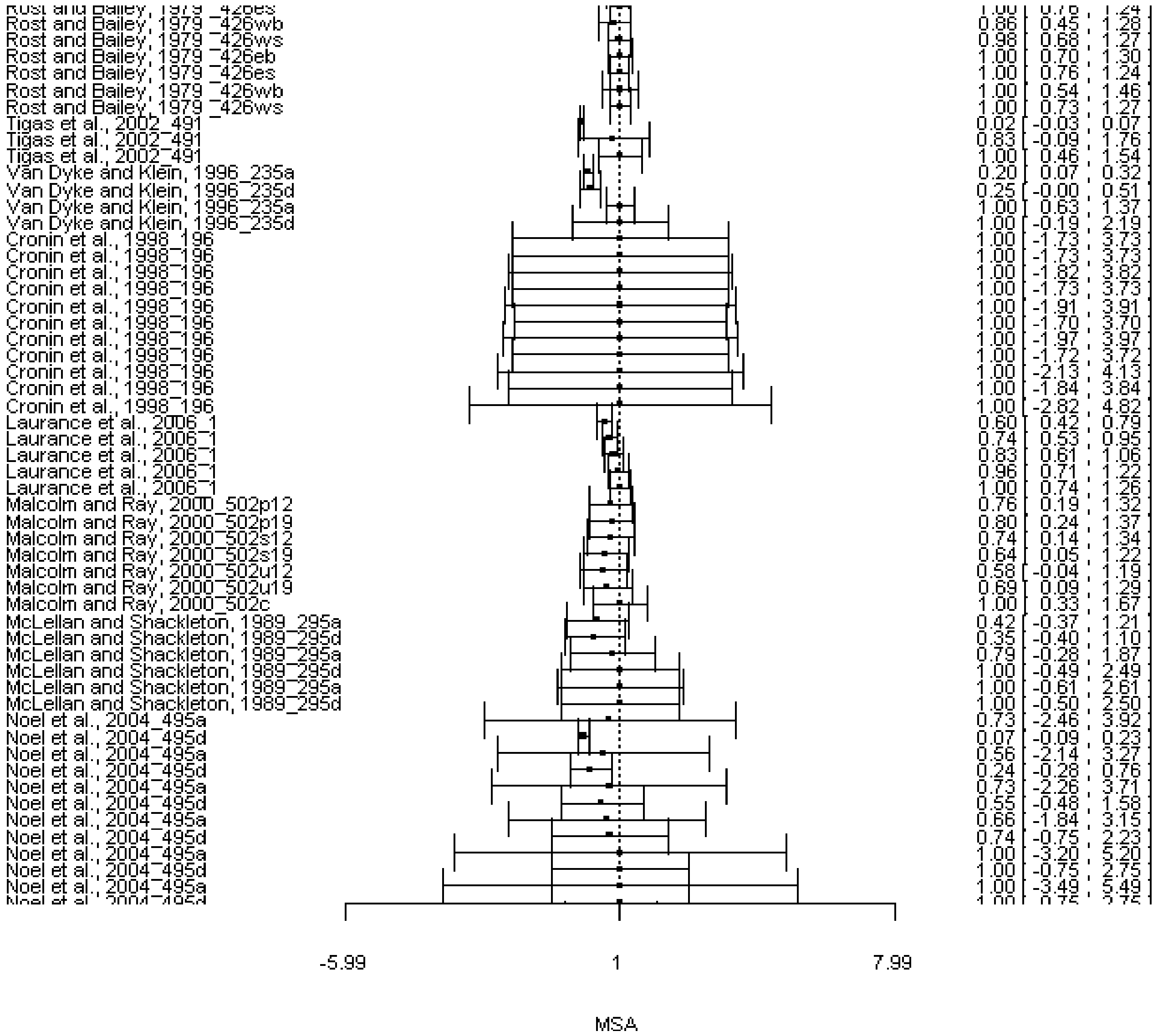
Figure 52. Funnel plot of the meta-analysis of bird species abundance at the distance interval 1800-2000 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

Appendix 2. Forest and funnel plots with the results of the meta-analysis for mammal species for different distance intervals.

a) Upper part of the forest plot for the meta-analysis for all distances.



b) Middle part of the forest plot for the meta-analysis for all distances.



c) Lower part of the forest plot for the meta-analysis for all distances.

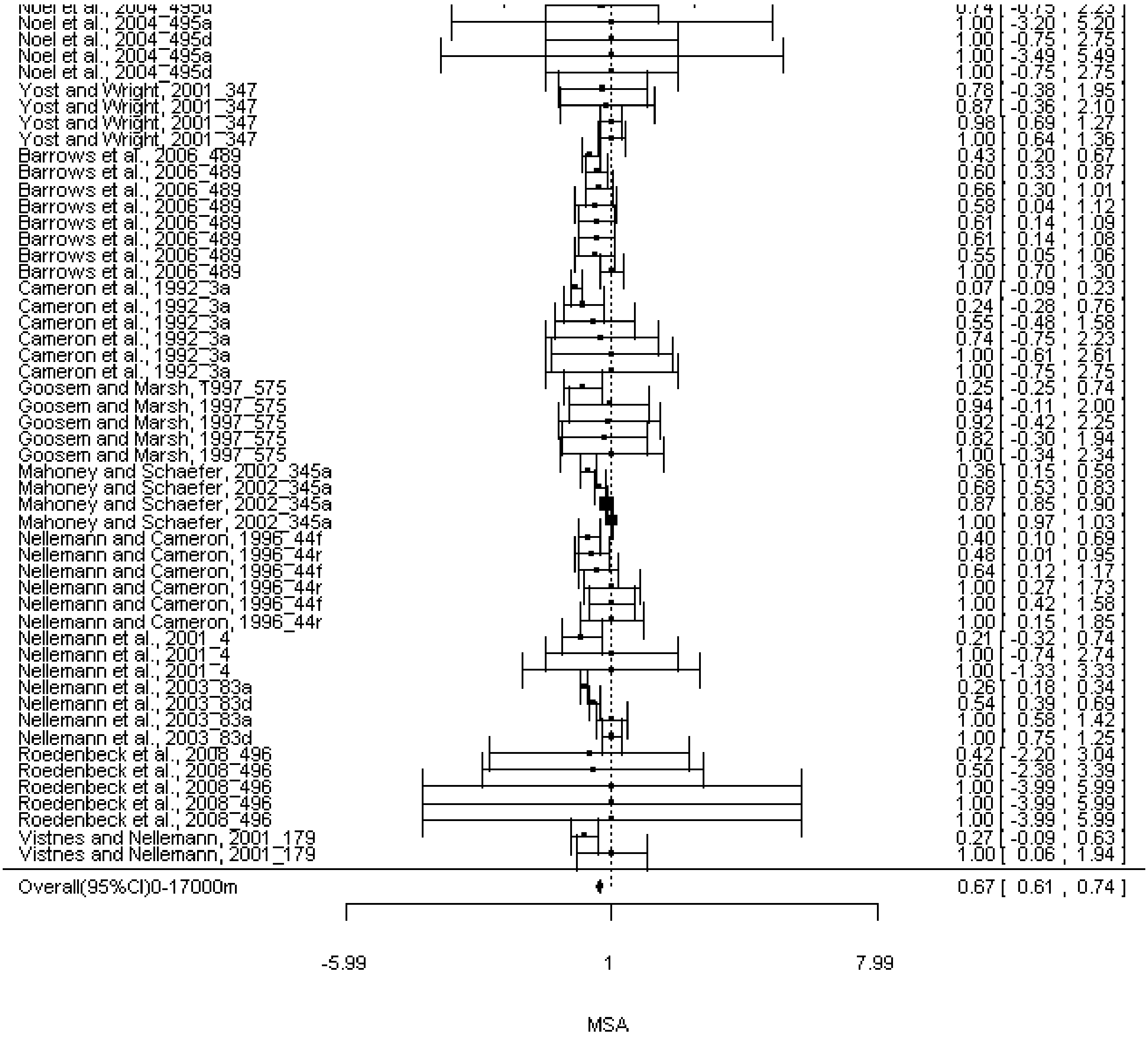


Figure 53. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at all distances (0-17000 m). The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals. Note: The plot is divided in three parts so that it can be visualized.

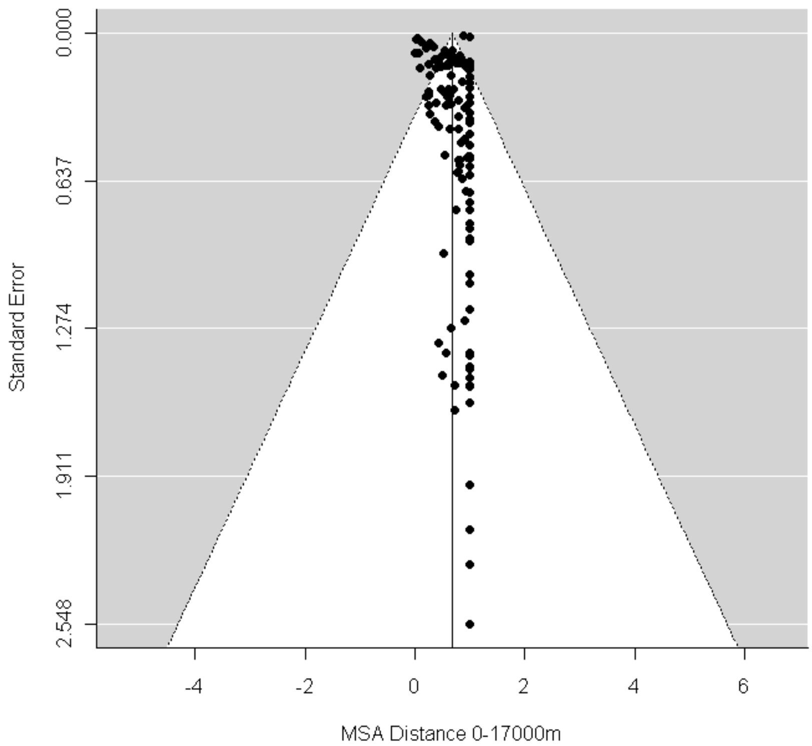


Figure 54. Funnel plot of the meta-analysis of bird species abundance at all distances (0-17000 m) from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

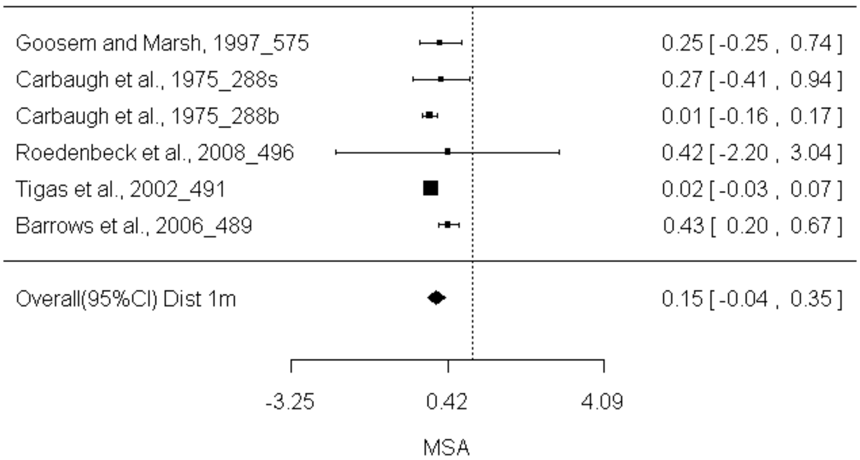


Figure 55. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval: 1 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

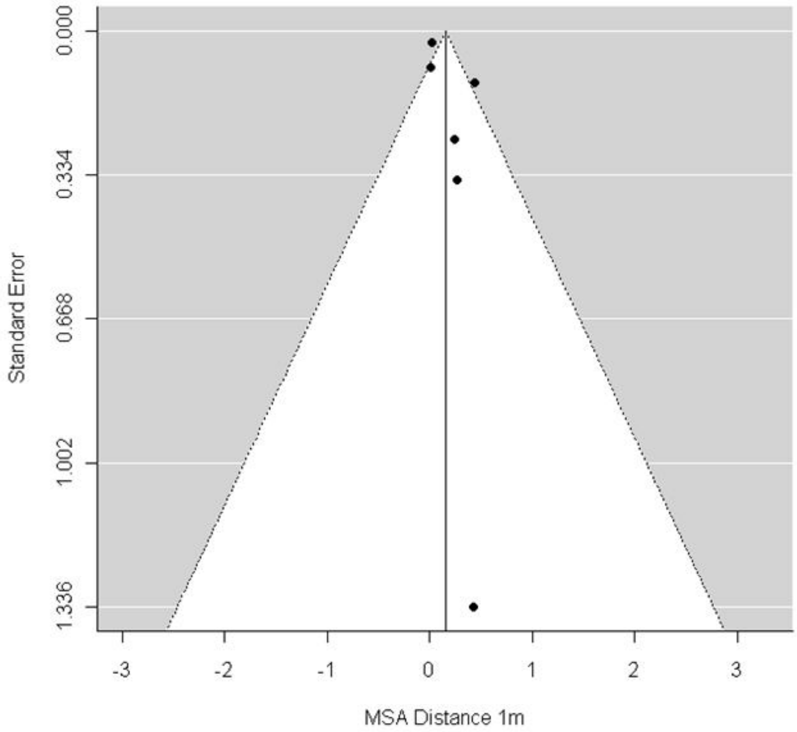


Figure 56. Funnel plot of the meta-analysis of bird species abundance at the distance interval: 1m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

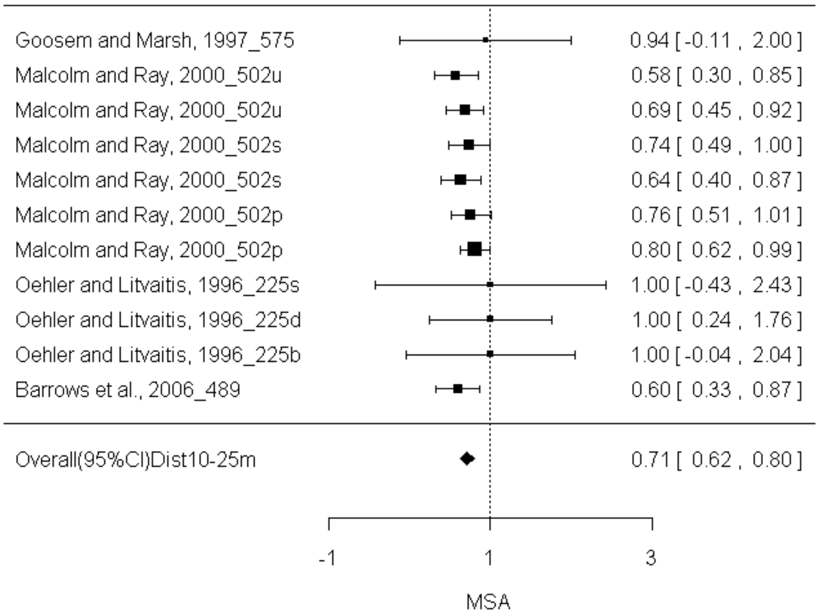


Figure 57. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 10-25 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

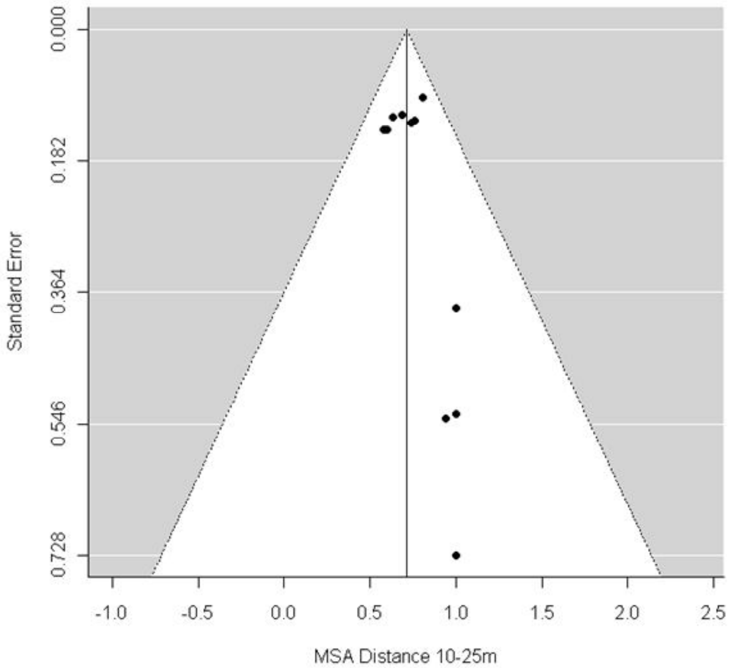


Figure 58. Funnel plot of the meta-analysis of bird species abundance at the distance interval 10-25 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

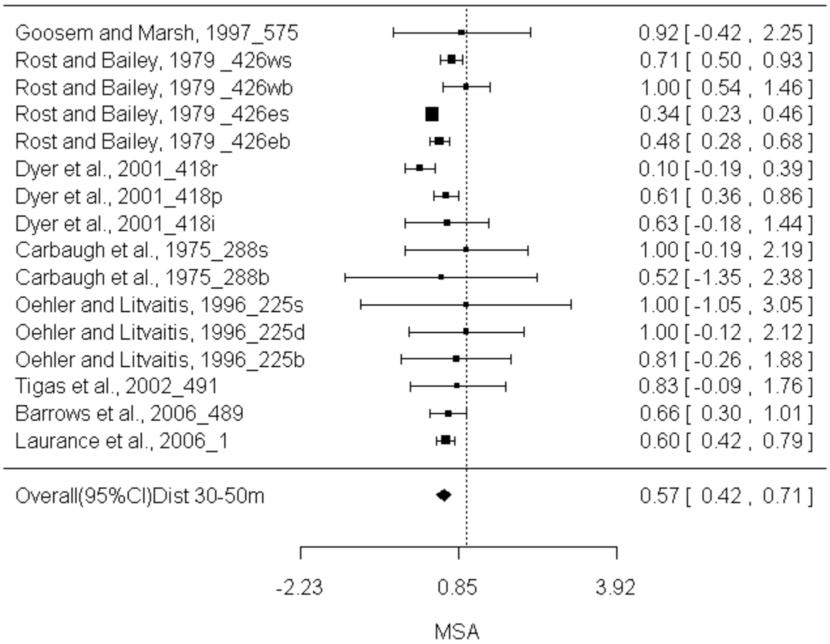


Figure 59. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 30-50 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

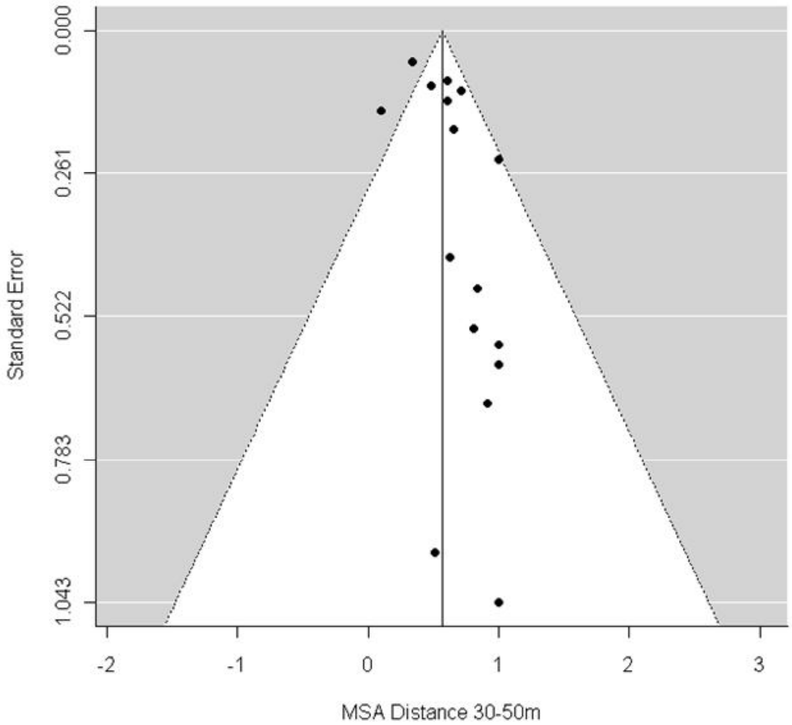


Figure 60. Funnel plot of the meta-analysis of bird species abundance at the distance interval 30-50 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

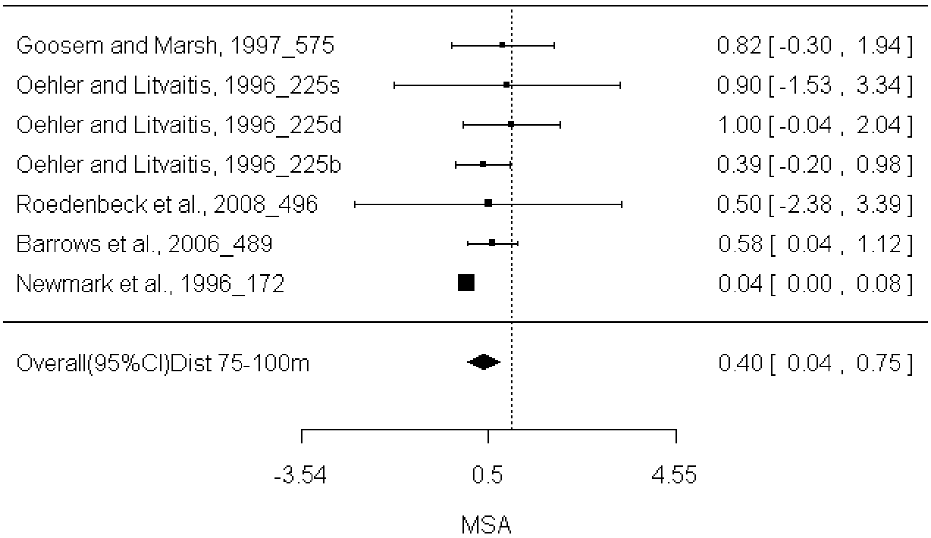


Figure 61. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 75-100 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

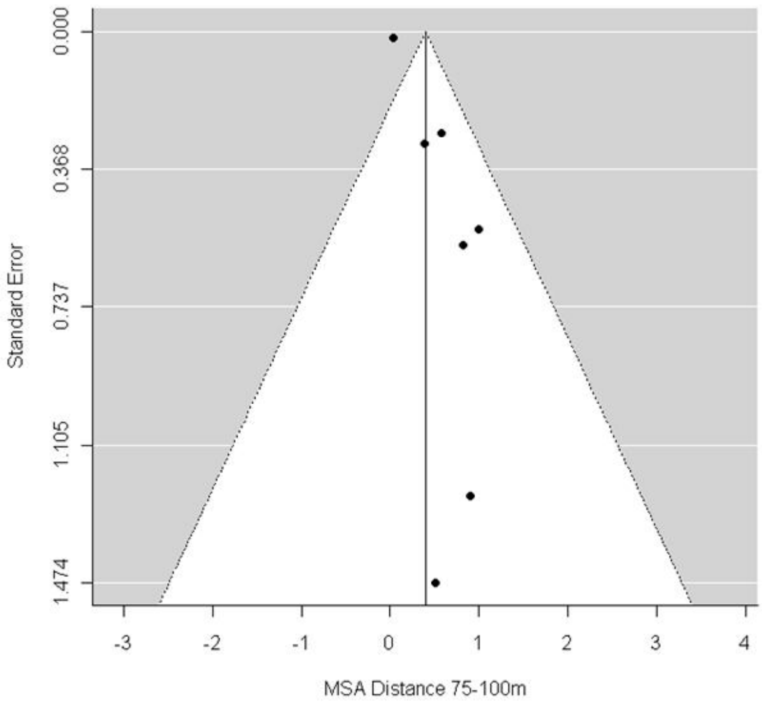


Figure 62. Funnel plot of the meta-analysis of bird species abundance at the distance interval 75-100 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

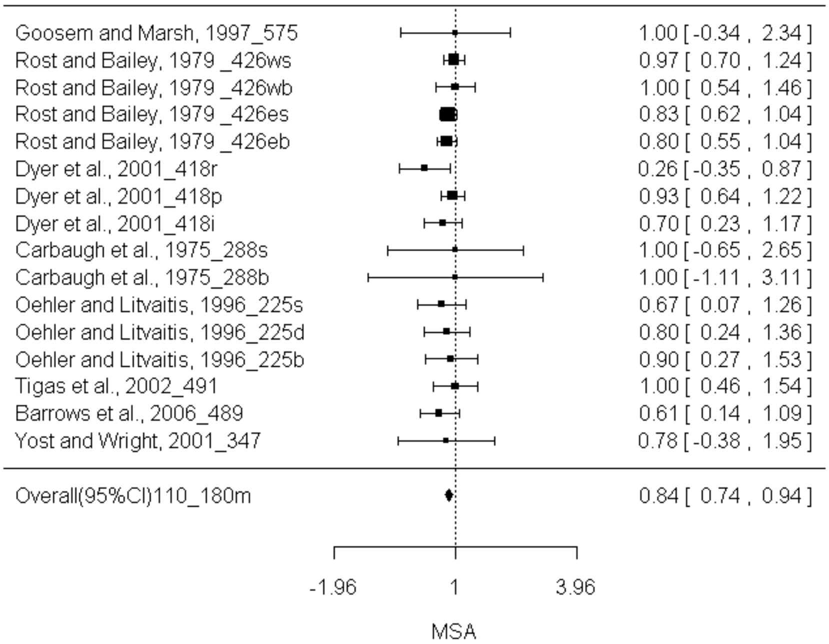


Figure 63. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 110-180 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

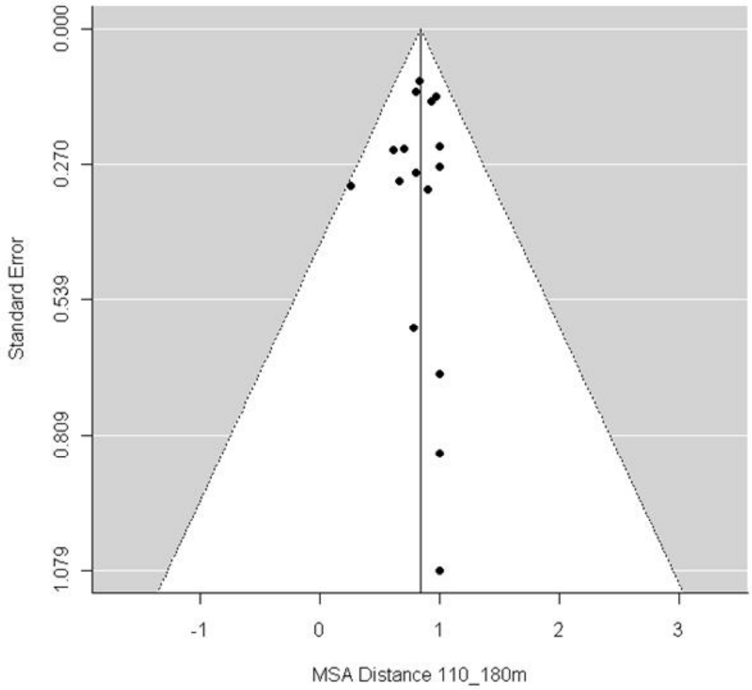


Figure 64. Funnel plot of the meta-analysis of bird species abundance at the distance interval 110-180m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

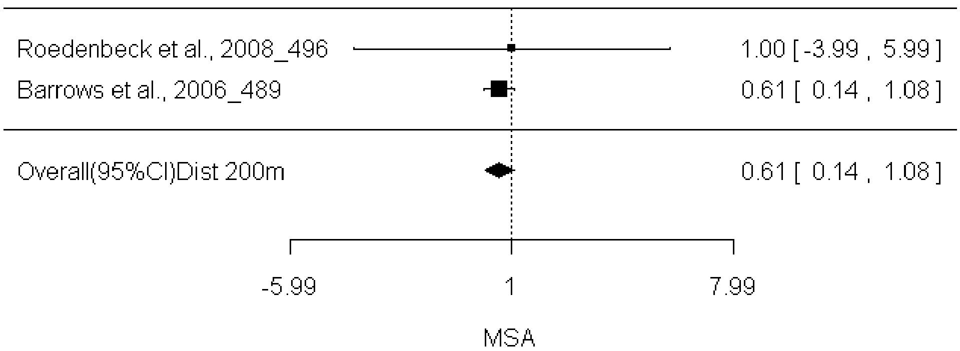


Figure 65. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 200 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

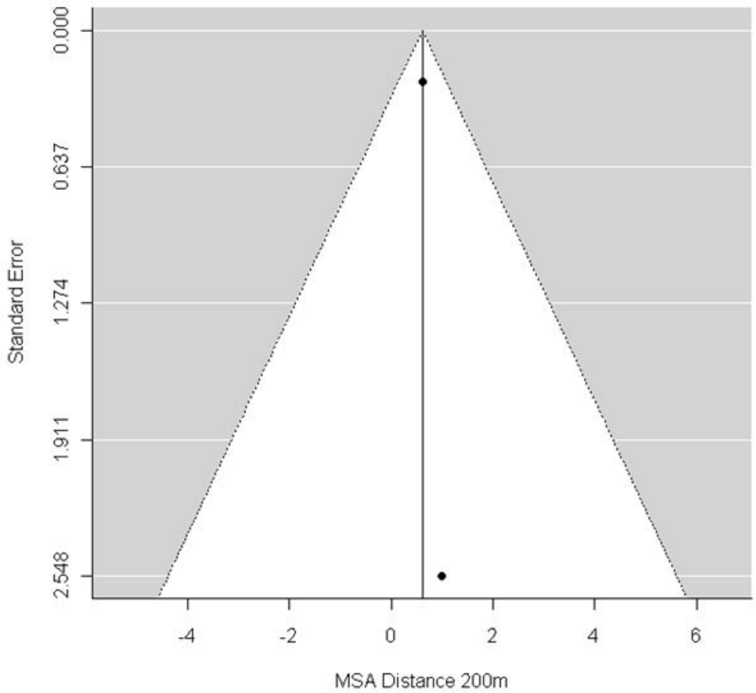


Figure 66. Funnel plot of the meta-analysis of bird species abundance at the distance interval 200 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

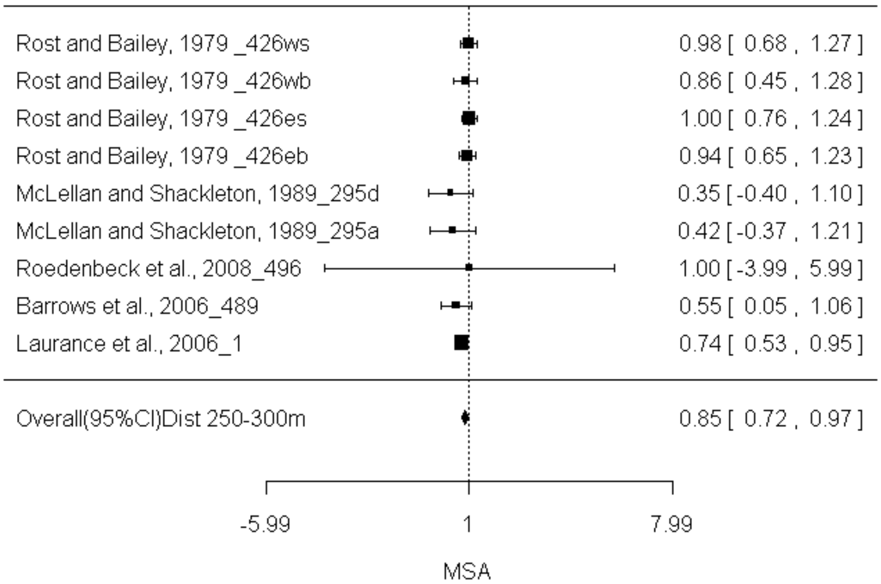


Figure 67. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 250-300 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

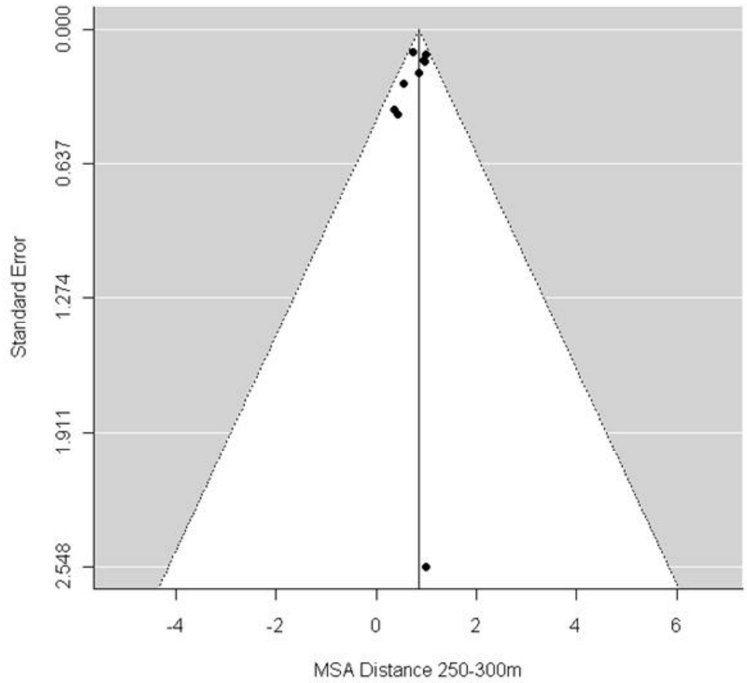


Figure 68. Funnel plot of the meta-analysis of bird species abundance at the distance interval 250-300 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

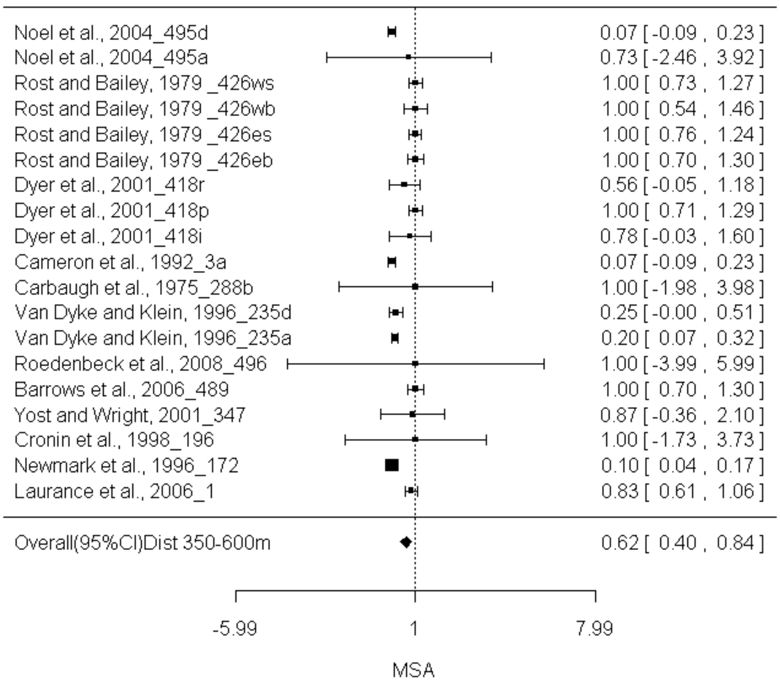


Figure 69. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 350-600 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

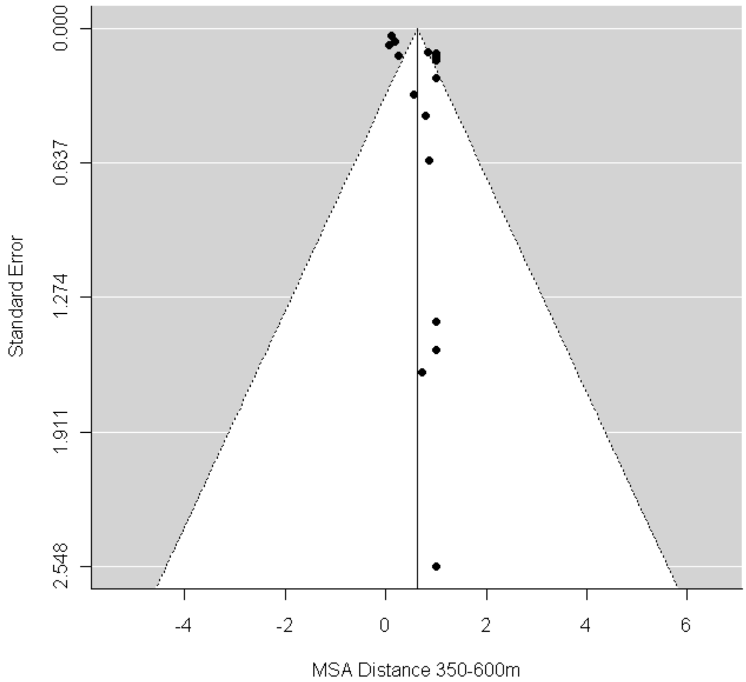


Figure 70. Funnel plot of the meta-analysis of bird species abundance at the distance interval 350-600 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

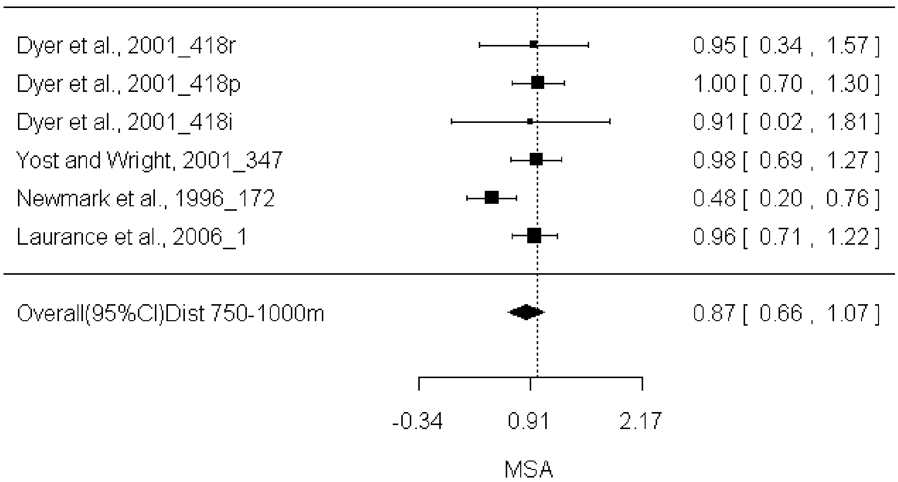


Figure 71. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 750-1000 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

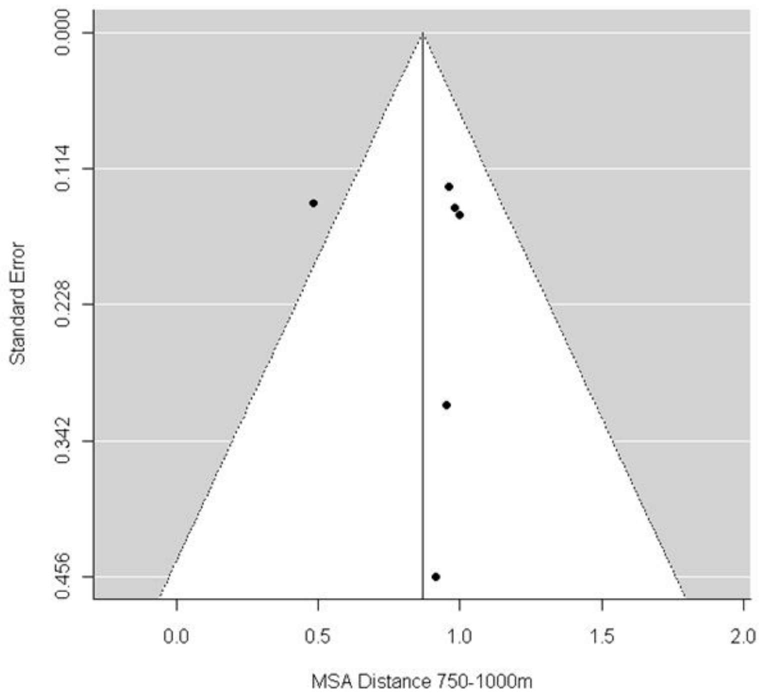


Figure 72. Funnel plot of the meta-analysis of bird species abundance at the distance interval 750-1000 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

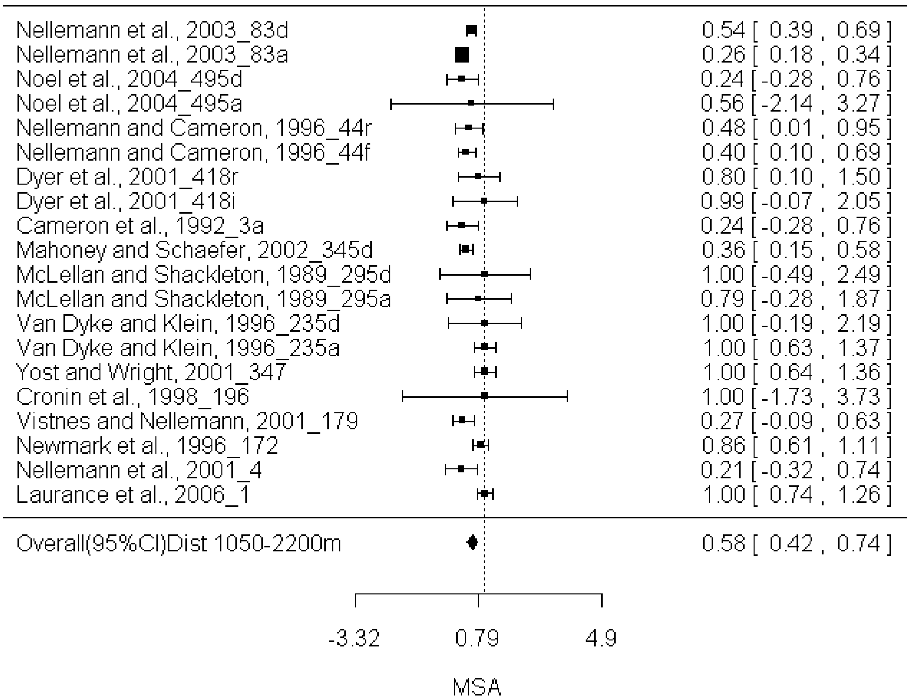


Figure 73. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 1050-2200 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

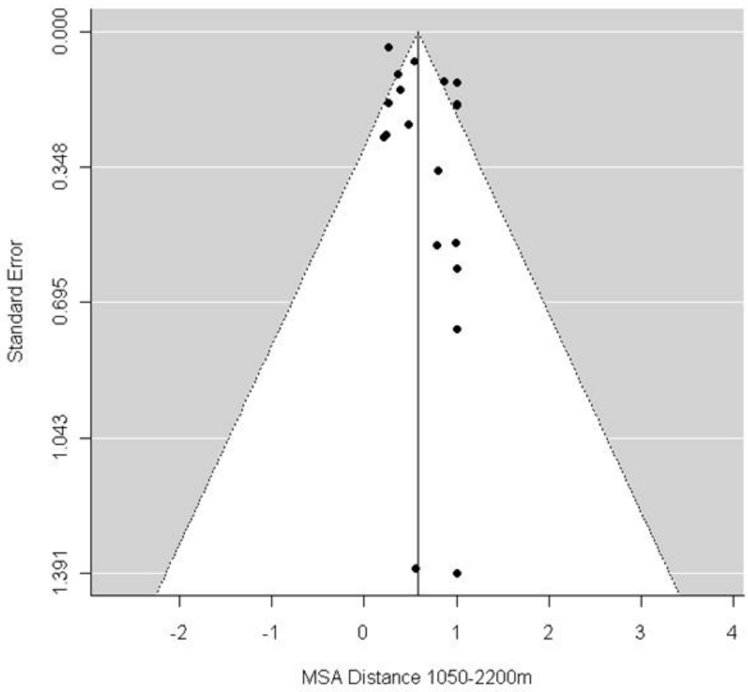


Figure 74. Funnel plot of the meta-analysis of bird species abundance at the distance interval 1050-2200 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

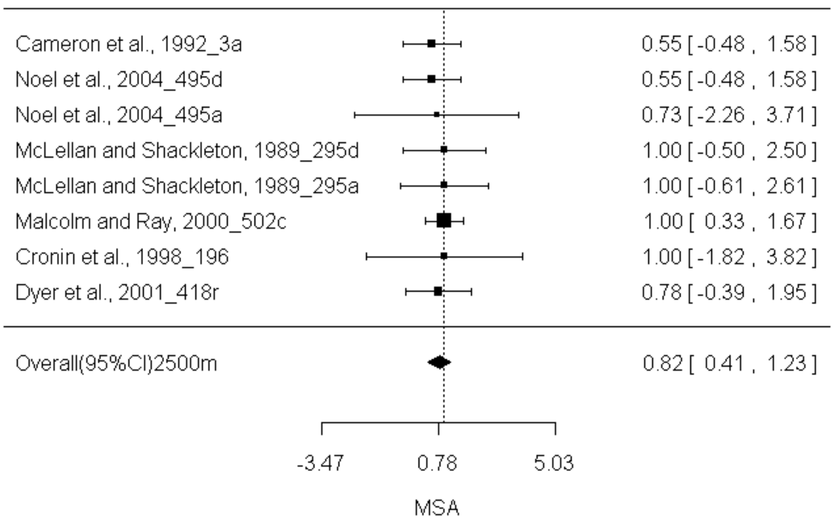


Figure 75. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 2500 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

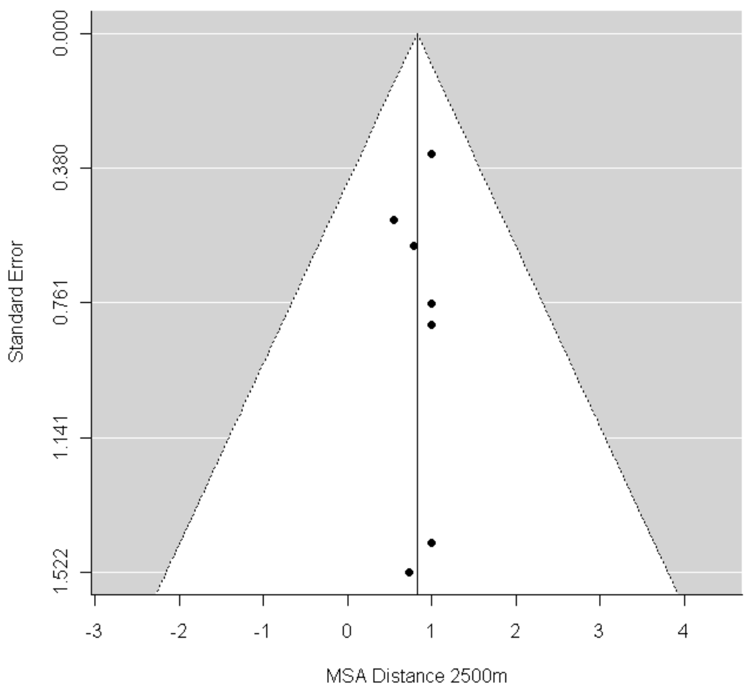


Figure 76. Funnel plot of the meta-analysis of bird species abundance at the distance interval 2500 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

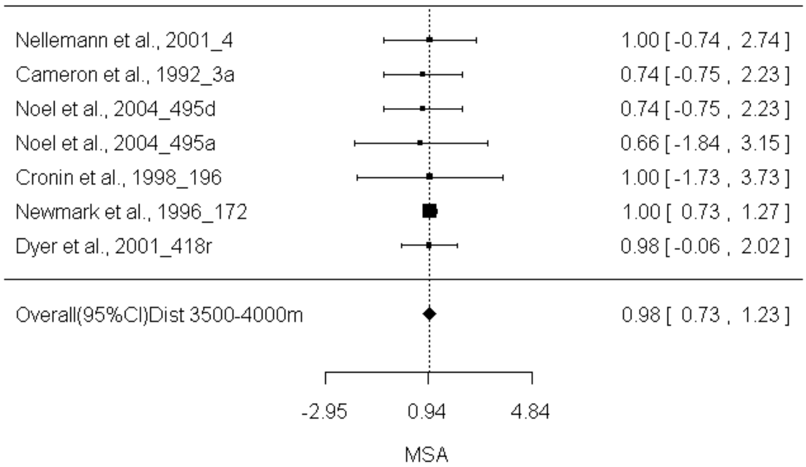


Figure 77. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 3500-4000 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

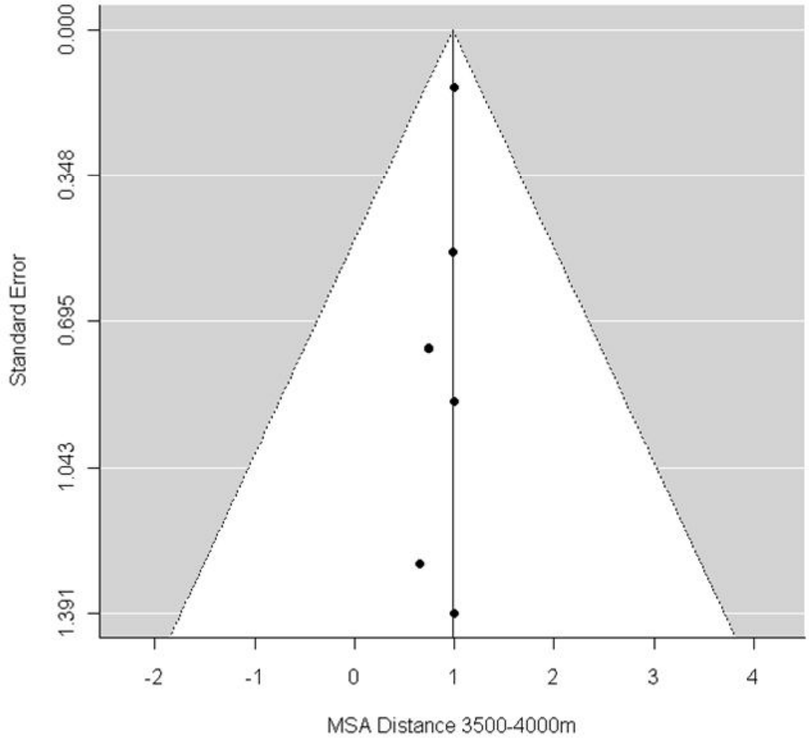


Figure 78. Funnel plot of the meta-analysis of bird species abundance at the distance interval 3500-4000 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

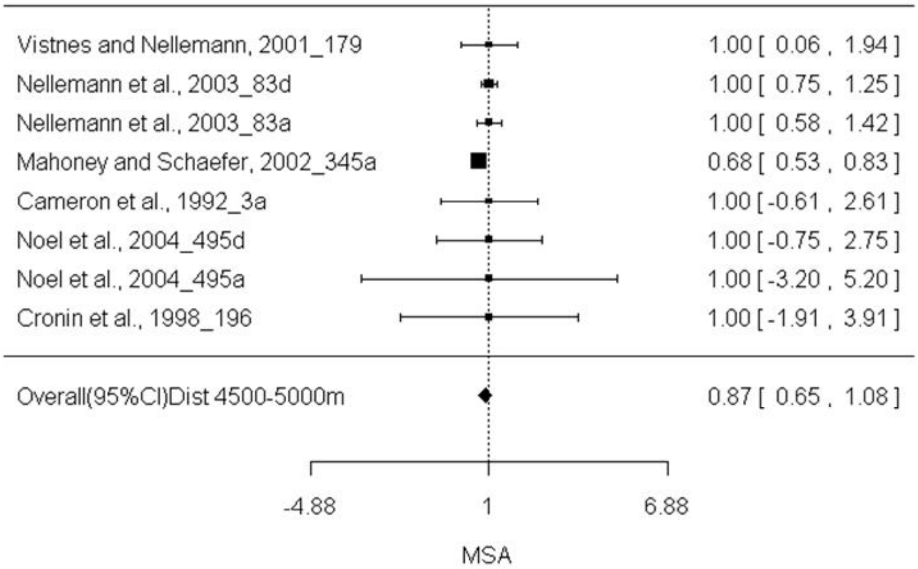


Figure 79. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 4500-5000 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

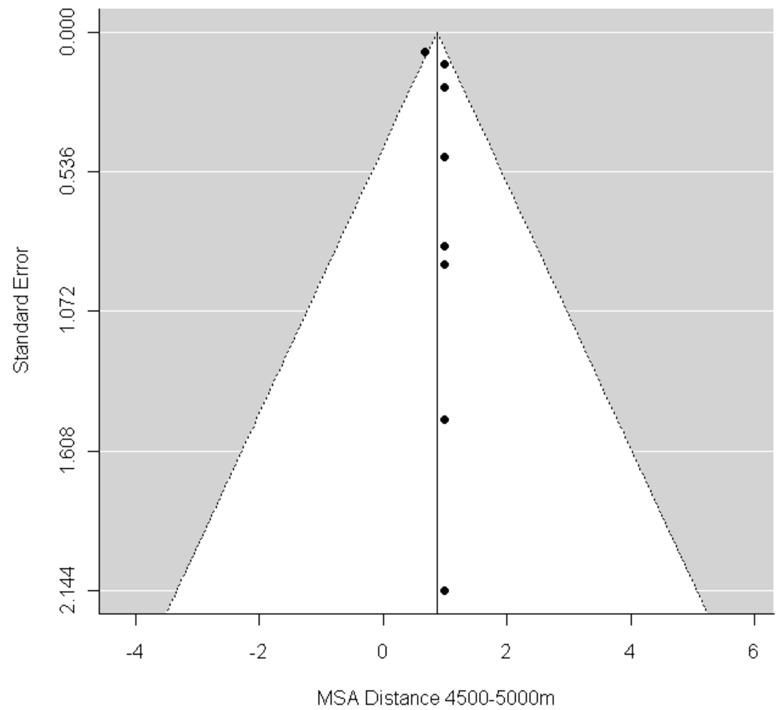


Figure 80. Funnel plot of the meta-analysis of bird species abundance at the distance interval 4500-5000 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

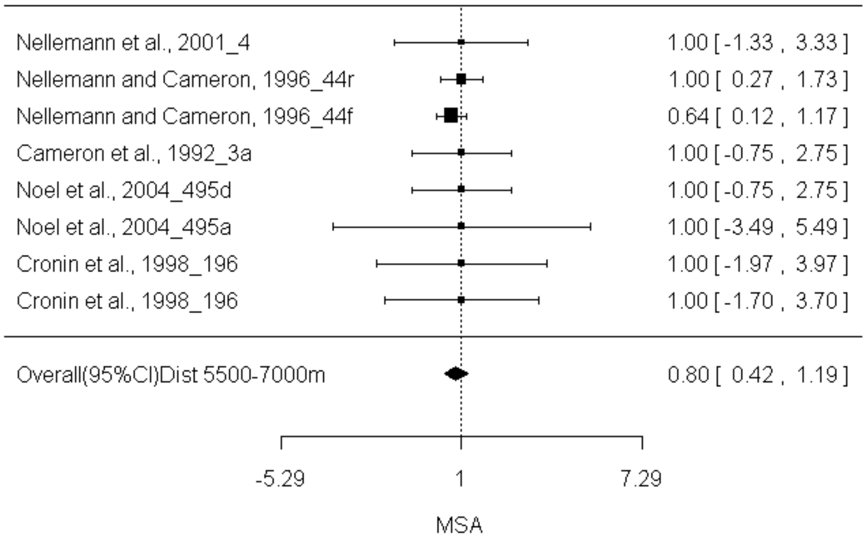


Figure 81. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 5500-7000 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

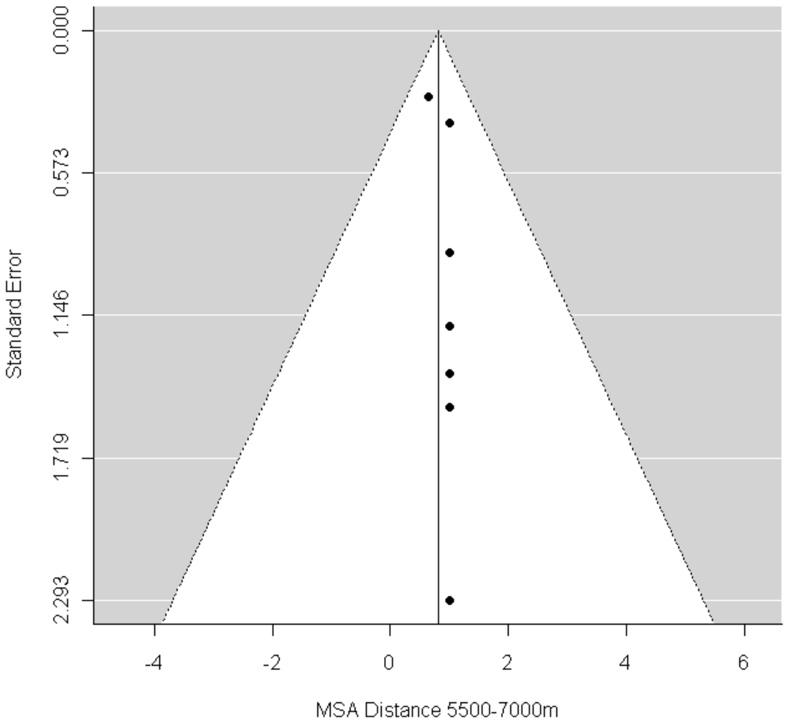


Figure 82. Funnel plot of the meta-analysis of bird species abundance at the distance interval 5500-7000 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

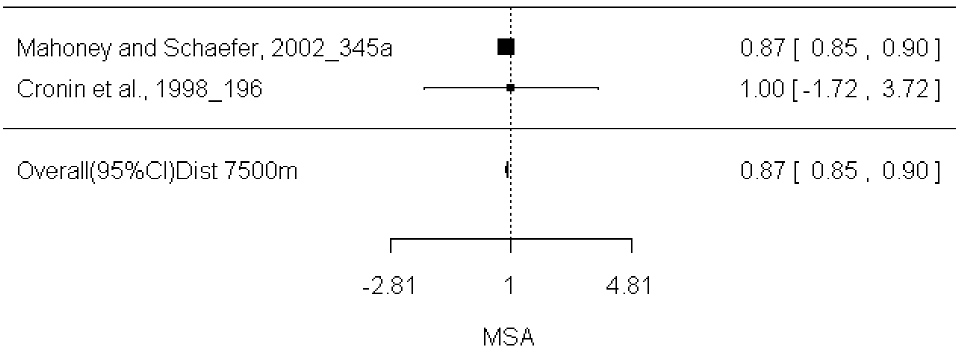


Figure 83. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 7500 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

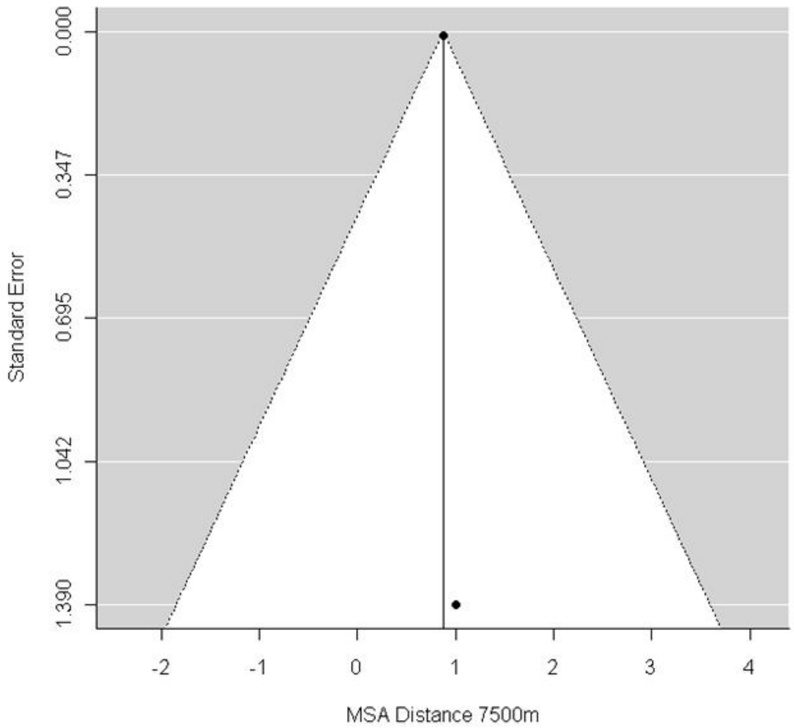


Figure 84. Funnel plot of the meta-analysis of bird species abundance at the distance interval 7500 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

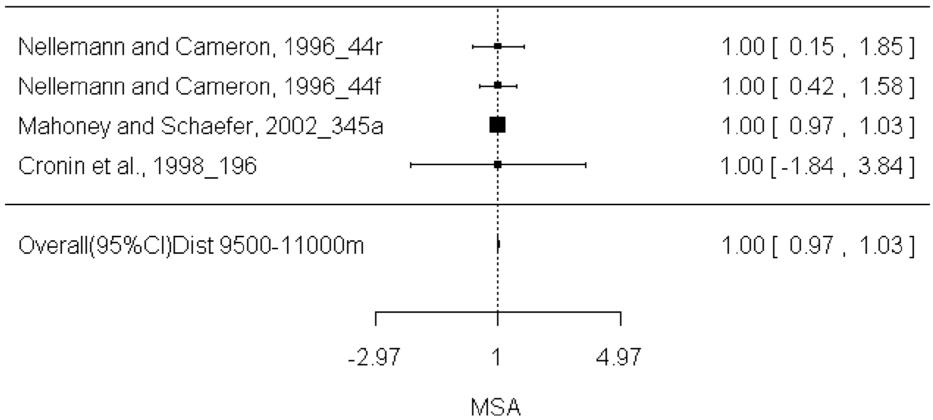


Figure 85. Forest plot illustrating the variation in effect sizes for studies (solid boxes) investigating the effect of infrastructure on mammal abundance at the distance interval 9500-11000 m from infrastructure. The solid vertical line represents the line of no effect (1) and the diamond indicates the pooled effect. Box sizes are drawn proportional to the inverse of the sampling variances. Error bars are 95% confidence intervals.

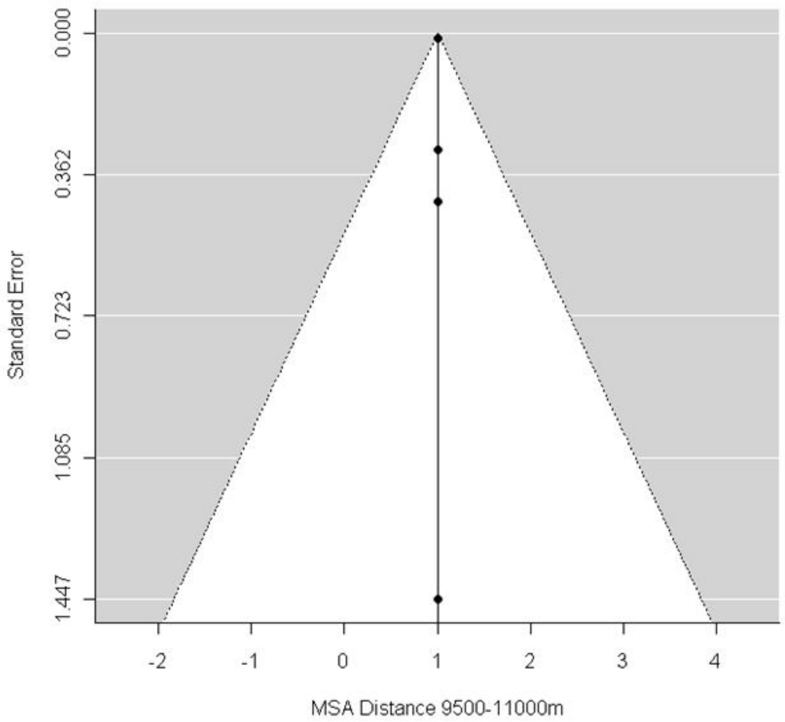


Figure 86. Funnel plot of the meta-analysis of bird species abundance at the distance interval 9500-11000 m from infrastructure. The study outcome (MSA) is plotted as a function of the corresponding standard error to assess publication bias.

Appendix 3. List of species included in the meta-analysis and number of studies and datasets that in which they were included. Some studies aggregated two or more species in order to increase sample size.

Mammal species	Nº studies	Nº datasets
Alces alces	1	1
Canis latrans	1	1
Canis latrans & Vulpes vulpes	1	3
Cephalophus sp	1	1
Cervus canadensis	2	4
Connochaetes taurinus	1	1
Cricetomys emini	1	7
Deomys ferrugineus	1	7
Dipodomys deserti	1	1
Equus quagga	1	1
Funisciurus leucogenys	1	7
Grammomys rutilans	1	7
Graphiurus sp	1	7
Heimyscus fumosus	1	7
Hybomys univittatus	1	7
Hylomyscus aeta	1	7
Hylomyscus alleni	1	7
Lepus europaeus	1	1
Lophuromys nudicaudus	1	7
Loxodonta africana	1	1
Loxodonta africana cyclotis	1	1

Lynx rufus	1	1
Melomys cervinipes	1	1
Odocoileus hemionus	1	4
Odocoileus virginianus	1	2
Praomys tullbergi	1	7
Rangifer tarandus	10	15
Rattus spp	1	1
Spermophilus tereticaudus	1	1
Stochomys longicaudatus	1	7
Taurotragus spp + Canis mesomelas + Redunca redunca	1	1
Uromys caudimaculatus	1	1
Ursus arctos	2	3

Bird species		
Acanthiza pusilla	1	1
Accipiter fasciatus	1	1
Accipiter gentilis	1	2
Acrocephalus palustris	1	1
Acrocephalus schoenobaenus	1	1
Aegithalos caudatus	2	3
Aegypius monachus	1	2
Agelaius phoeniceus	1	2
Aimophila ruficeps	1	1
Alauda arvensis	4	5
Alectoris rufa	2	3
Amphispiza belli	1	1
Anas clypeata	1	2
Anas crecca	1	1
Anas platyrhynchos	3	4
Anser albifrons & Anser fabalis	1	4
Anser brachyrhynchus	3	6
Anser brachyrhynchus & Anser anser	1	1
Anthus pratensis	4	6
Anthus trivialis	3	4
Aphelocoma coerulescens	1	1
Apus apus	2	4
Aquila adalberti	1	2
Aquila pennata	1	2
Aythya fuligula	1	2
Buteo buteo	4	6
Callipepla californica	1	1
Calypte anna	1	1
Calypte costae	1	1
Cardinalis cardinalis	1	1
Carduelis cannabina	1	3
Carduelis carduelis	1	3
Carduelis chloris	3	5
Carduelis psaltria	1	1
Carduelis spinus	1	1
Carpodacus erythrinus	1	1
Carpodacus mexicanus	1	1
Certhia brachydactyla	2	3

Certhia familiaris	2	2
Chamaea fasciata	1	1
Chondestes grammacus	1	1
Chroicocephalus ridibundus	1	1
Circaetus gallicus	1	1
Circus cyaneus	1	2
Circus pygargus	1	2
Coccothraustes coccothraustes	2	2
Coccyzus americanus	1	1
Colluricincla harmonica	1	1
Columba bollii	1	1
Columba livia	1	1
Columba oenas	2	2
Columba palumbus	4	5
Coracina novaehollandiae	1	1
Cormobates leucophaea	1	1
Corvus corone	4	6
Corvus monedula	1	1
Corvus orru	1	1
Cracticus nigrogularis	1	1
Cuculus canorus	3	3
Cyanocitta cristata	1	1
Cygnus olor	2	3
Dendrocopos major	4	4
Dendrocopos minor	1	1
Dicrurus bracteatus	1	1
Dryocopus martius	1	1
Emberiza cirlus	1	3
Emberiza citrinella	3	3
Emberiza hortulana	1	1
Emberiza schoeniclus	2	2
Empidonax virescens	1	1
Eopsaltria australis	1	1
Eremophila alpestris	1	2
Erithacus rubecula	6	9
Falco tinnunculus	4	6
Falco tinnunculus & Falco naumanni	1	1
Ficedula hypoleuca	2	2
Fringilla coelebs	6	9
Fulica atra	1	2
Gallinago gallinago	1	1
Garrulus glandarius	3	5
Gerygone olivacea	1	1
Gyps fulvus	2	4
Haematopus ostralegus	3	7
Haliaeetus leucocephalus	1	1
Hippolais icterina	1	1
Hippolais polyglotta	1	3
Hirundo rustica	2	4
Hylocichla mustelina	1	1
Hylophilus ochraceiceps	1	1
Larus argentatus	1	1

Larus canus	1	1
Lichenostomus chrysops	1	1
Limosa limosa	2	7
Loxia sp.	1	1
Luscinia megarhyncos	1	2
Malurus lamberti	1	1
Manorina melanocephala	1	1
Melanerpes carolinus	1	1
Melithreptus albogularis	1	1
Miliaria calandra	1	1
Milvus migrans	3	3
Milvus milvus	1	2
Mimus polyglottos	1	1
Mniotilta varia	1	1
Molothrus ater	1	1
Motacilla alba	2	2
Motacilla flava	1	2
Muscicapa striata	3	5
Myiagra rubecula	1	1
Myiarchus crinitus	1	1
Myrmotherula gutturalis	1	1
Myrmotherula longipennis	1	1
Myrmotherula menetriesii	1	1
Myzomela sanguinolenta	1	1
Numenius arquata	1	1
Oenanthe oenanthe	2	2
Oporornis formosus	1	1
Oriolus oriolus	1	1
Otis tarda	1	5
Pachycephala pectoralis	1	1
Pachycephala rufiventris	1	1
Pardalotus striatus	1	1
Parus ater	4	5
Parus caeruleus	5	8
Parus cristatus	3	3
Parus major	4	7
Parus montanus	2	3
Parus palustris	1	1
Passer domesticus	1	1
Passer montanus	1	1
Pernis apivorus	1	1
Phasianus colchicus	3	4
Philemon corniculatus	1	1
Philydor erythocercum	1	1
Phoenicurus ochruros	1	1
Phoenicurus phoenicurus	3	4
Phylloscopus bonelli	1	2
Phylloscopus canariensis	1	1
Phylloscopus collybita	2	5
Phylloscopus sibilatrix	2	2
Phylloscopus trochilus	4	6
Pica pica	4	6

Picoides pubescens	1	1
Picoides villosus	1	1
Picus viridis	1	1
Pipilo crissali	1	1
Pipilo erythrophthalmus	2	2
Piranga olivacea	1	1
Piranga rubra	1	1
Platycercus adscitus	1	1
Polioptila californica	1	1
Prunella modularis	3	4
Psaltriparus minimus	1	1
Pyrrhula pyrrhula	2	2
Regulus ignicapillus	2	3
Regulus regulus	4	5
Rhipidura albiscapa	1	1
Riparia riparia	1	1
Saxicola rubetra	1	1
Saxicola torquata	1	3
Scolopax rusticola	1	1
Seiurus aurocapillus	2	2
Serinus canarius	1	1
Serinus serinus	1	3
Sitta carolinensis	1	1
Sitta europaea	3	3
Spizella atrogularis	1	1
Streptopelia turtur	1	3
Sturnella neglecta	1	1
Sturnus vulgaris	3	3
Sylvia atricapilla	3	6
Sylvia borin	2	2
Sylvia cantillans	1	1
Sylvia communis	1	1
Sylvia curruca	1	1
Sylvia melanocephala	1	1
Sylvia undata	1	2
Tetrao tetrix	1	1
Thamnomanes ardesiacus	1	1
Thamnomanes caesius	1	1
Thryomanes bewickii	1	1
Thryothorus ludovicianus	1	1
Tolmomyias assimilis	1	1
Toxostoma redivivum	1	1
Trichoglossus chlorolepidotus	1	1
Trichoglossus haematodus	1	1
Tringa ochropus	1	1
Tringa totanus	2	3
Troglodytes troglodytes	5	7
Turdus iliacus	2	2
Turdus merula	5	8
Turdus philomelos	4	6
Turdus pilaris	2	2
Turdus viscivorus	1	1

Upupa epops	1	1
Vanellus vanellus	3	8
Vireo olivaceus	1	1
Wilsonia citrina	1	1
Xiphorhynchus pardalotus	1	1
Zenaida macroura	1	1
Zosterops lateralis	1	1

Appendix 4. Results of the sensitivity analysis after removing studies that scored medium-low quality in the study quality assessment.

Table A4.1. Bird species

Distance(m)	k	Effect size	SE	CI.(lb)	CI.(ub)	P(e.size)	Q	P(Q)	I^2 (%)	Egger´s test intercept	P(t) Egger	Fail-safe N
0-2000(alldist.)	180[4]	0.6831	0.0288	0.6267	0.7395	**<0.0001**	2653.70	**<0.0001**	89.7	4.699	**<0.0001**	**264275**
<10	8	0.4173	0.1474	0.1284	0.7062	**0.0046**	61.86	**<0.0001**	96.2	3.038	**0.0042**	**227**
15-35	17	0.4837	0.0902	0.3070	0.6604	**<0.0001**	223.76	**<0.0001**	93.7	4.542	**0.0006**	**2187**
38-65	16	0.6327	0.0950	0.4465	0.8189	**<0.0001**	140.49	**<0.0001**	86.2	4.143	**0.0001**	**1608**
70-80	12	0.5847	0.1214	0.3468	0.8226	**<0.0001**	29.76	**0.0017**	58.3	2.175	**0.0011**	**240**
90-100	13	0.6176	0.1010	0.4197	0.8155	**<0.0001**	32.68	**0.0011**	66.5	3.093	**0.0022**	**585**
110-125	9	0.6443	0.1316	0.3865	0.9022	**<0.0001**	32.30	**0.0001**	69.4	2.9055	**0.0019**	**244**
130-140	4	0.9230	0.0760	0.7740	1.0719	**<0.0001**	1.95	0.5833	0	5.348	0.0521	**166**
150-160	11	0.6086	0.0964	0.4197	0.7974	**<0.0001**	45.38	**0.0001**	80.5	4.935	**0.0047**	**885**
170-180	9	Fisher scoring algorithm did not converge										
190-200	8	0.7552	0.0416	0.6737	0.8367	**<0.0001**	3.73	0.8106	0	5.028	**0.0134**	**591**
210-240	7	0.8415	0.1030	0.6397	1.0434	**<0.0001**	9.99	**0.125**	38.9	4.746	0.0744	**402**
250-280	12	0.6764	0.1243	0.4327	0.9200	**<0.0001**	274.16	**<0.0001**	97.6	11.018	**0.0352**	**6453**
300-320	11	0.9460	0.0688	0.8112	1.0808	**<0.0001**	1.20	0.9996	0	3.291	**0.0022**	**474**
340-375	6	0.8312	0.0636	0.7065	0.9558	**<0.0001**	6.22	0.2851	32.6	6.442	0.0542	**546**
380-490	8	0.9980	0.0240	0.9509	1.0451	**<0.0001**	0.40	0.9997	0	12.373	**0.0044**	**3615**
500-565	7	0.5691	0.1685	0.2388	0.8993	**<0.0001**	41.59	**<0.0001**	82.9	2.9195	**0.0179**	**148**
600-645	2	0.7308	0.1335	0.4692	0.9924	**<0.0001**	0.31	0.5753	0	7.186	0.0506	17
650-785	4	0.5793	0.1859	0.2149	0.9437	**0.0018**	2.01	0.5694	0	1.650	**0.0083**	13
800-860	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
900-915	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1000-1075	7	0.9223	0.0839	0.7578	1.0867	**<0.0001**	3.03	0.8049	14.65	4.294	0.0814	**328**
1100-1175	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1200-1290	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1300	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1400	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1500-1505	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1600	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1700-1750	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1800-2000	2	1.0000	0.0515	0.8990	1.1010	**<0.0001**	0.0000	1.0000	0	10.648	0.435	**166**

[4] Total number of data points or MSA values included in the sensitivity analysis for bird species. Eight studies and 14 datasets that scored "low-medium" quality in the study quality assessment were removed for this analysis.

Table A4.2. Mammal species.

Distance(m)	k	Effect size	SE	CI.(lb)	CI.(ub)	P(e.size)	Q	P(Q)	I^2 (%)	Egger´s test intercept	P(t) Egger	Fail-safe N
0-17000	132[5]	0.6779	0.0354	0.6086	0.7472	**<0.0001**	3401.70	**<0.0001**	91.5	4.0060	**<0.0001**	**103132**
1	4	0.2120	0.1451	-0.0724	0.4965	0.1440	12.16	**0.0069**	71.6	1.4194	0.154	8
10-25	8	0.6664	0.0904	0.4892	0.8436	**<0.0001**	0.98	0.9952	0	2.5163	**<0.0001**	**142**
30-50	11	0.5468	0.0752	0.3995	0.6941	**<0.0001**	26.53	**0.0031**	65.5	3.7799	**0.0002**	**628**
75-100	4	0.3204	0.2354	-0.1410	0.7818	0.1735	5.84	0.1196	53.7	1.5076	**0.0372**	**10**
110-180	11	0.8414	0.0547	0.7342	0.9487	**<0.0001**	6.98	0.7271	0	4.0545	**0.0003**	**724**
200	2	0.6104	0.2382	0.1435	1.0774	**0.0104**	0.02	0.8780	0	1.464	0.402	2
250-300	9	0.8470	0.0627	0.7241	0.9698	**<0.0001**	7.78	0.4557	7.8	4.059	**0.0037**	**485**
350-600	18	0.6204	0.1121	0.4007	0.8400	**<0.0001**	206.46	**<0.0001**	92.4	3.506	**<0.0001**	**1455**
750-1000	6	0.8669	0.1052	0.6608	1.0731	**<0.0001**	9.23	0.1002	50.2	4.843	**0.0036**	**307**
1050-2200	20	0.5786	0.0806	0.4207	0.7366	**<0.0001**	75.49	**<0.0001**	74.1	3.0049	**<0.0001**	**1316**
2500	8	0.8233	0.2098	0.4121	1.2345	**<0.0001**	0.9453	0.9957	0	1.2516	**0.0020**	30
3500-4000	7	0.9807	0.1276	0.7307	1.2308	**<0.0001**	0.2907	0.9995	0	1.9095	0.0775	**60**
4500-5000	8	0.8666	0.1099	0.6512	1.0820	**<0.0001**	6.06	0.5323	30.8	3.395	**0.0255**	**265**
5500-7000	8	0.8049	0.1983	0.4163	1.1936	**<0.0001**	0.8083	0.9974	0	1.2467	**0.0039**	29
7500	2	0.8730	0.0118	0.8498	0.8962	**<0.0001**	0.0084	0.9272	0	37.35	0.494	**2047**
8500	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
9500-11000	4	1.0000	0.0131	0.9744	1.0256	**<0.0001**	0	1	0	76.122	**<0.0001**	**2527**
17000	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

[5] Total number of data points or MSA values included in the sensitivity analysis for mammal species. Two studies and 5 datasets that scored “low-medium” quality in the study quality assessment were removed for this analysis.

Appendix 5. Reference list of all included studies

Ballasus. H., Sossinka, R. 1997. The impact of power lines on field selection and grazing intensity of wintering White-fronted- and Bean Geese *Anser albifrons, A. fabalis.* Journal für Ornithologie. 138: 215-228. 61

Barrios, L., Rodriguez, A. 2004.Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. Journal of Applied Ecology, 41, 72-81.

Barrows, C.W., Allen, M.F., Rotenberry, J.T. 2006. Boundary processes between a desert sand dune community and an encroaching suburban landscape. Biological Conservation, 131, 486-494.

Bautista, L.M., García, J.T., Calmaestra, R.G., Palacin, C., Martín, C.A., Morales, M.B., Bonal, R., Viñuela, J. 2004. Effect of weekend road traffic on the use of space by raptors. Conservation Biology, 18: 726-732.

Bolger, D.T., Scott, T.A., Rotenberry, J.T. 1997. Breeding bird abundance in an urbanizing landscape in coastal Southern California. Conservation Biology, 11, 406-421.

Cameron, R.D., Reed, D.J., Dau, J.R., Smith, W.T. 1992. Redistribution of calving caribou in response to oil field development on the Arctic Slope of Alaska. Arctic, 45, 338-342.

Carbaugh, B., Vaughan, J.P., Bellis, E.D., Graves, H.B. 1975. Distribution and activity of white-tailed deer along an interstate highway. Journal of Wildlife Management, 39, 570-581.

Clark, W.D., Karr, J.R. 1979. Effects of highways on Red-winged Blackbird and Horned Lark populations. Wilson Bulletin, 81, 143-145.

Cronin, M.A., Amstrup, S.C., Durner, G.M., Noel, L.E., McDonald, T.L., Ballard, W. 1998. Caribou distribution during the post-calving period in relation to infrastructure in the Prudhoe Bay oil field, Alaska. Arctic, 51, 85-93.

Delgado, J.D., Arévalo, J.R., Fernández-Palacios, J.M. 2004. Consecuencias de la fragmentación viaria: Efectos de borde de las carreteras en la laurisilva y el pinar de Tenerife., in: Fernández-Palacios, J.M., Morici, C.(Eds.), Ecología Insular/Island Ecology. Asociación Española de Ecología Terrestre (AEET)-Cabildo Insular de La Palma, pp. 181-225. 63

Develey, P.F., Stouffer, P.C. 2001. Effects of roads on movements by understorey birds in mixed-species flocks in Central Amazonian Brazil. Conservation Biology, 15, 1416-1422.

Devereux, C.L., Denny, M.J.H., Whittingham, M.J. 2008. Minimal effects of wind turbines on the distribution of wintering farmland birds. Journal of Applied Ecology 45, 1689-1694.

Dyer, S.J., O'Neill, J.P., Wasel, S.M., Boutin, S. 2001. Avoidance of industrial development by woodland caribou. Journal of wildlife management, 65, 531-542.

Gill, J.A., Sutherland, W.J., Watkinson, A.R. 1996. A method to quantify the effects of human disturbance on animal populations. Journal of Applied Ecology, 33, 786-792.

Goosem, M., Marsh, H. 1997. Fragmentation of a small-mammal community by a powerline corridor through tropical rainforest. Wildlife Research 24, 613-629.

Hüppop, V.O., Hüppop, K, 1995. The influence of agriculture and road usage on the distribution of coastal bird nests on saltmarshes in Schleswig-Holstein (Germany). Die Vogelwarte, 38, 76-88.

Joly, K., Nellemann, C., Vistnes, I. 2006. A reevaluation of caribou distribution near an oilfield road on Alaska's North Slope. Wildlife Society Bulletin, 34, 866-869.

Keller, V.E. 1991.The effect of disturbance from roads on the distribution of feeding sites of geese *(Anser brachyrhynchus, A. anser),* wintering in North-Scotland. Ardea 79. 229-232.

Kroodsma, R.L. 1984. Effect of edge on breeding forest bird species. Wilson Bulletin, 96, 426-436.

Kuitunen, M., Rossi, E., Stenroos, A. 1998. Do highways influence density of land birds? Environmental Management, 22, 297-302.

Lane, S.J., Alonso, J.C., Martín, C.A. 2001. Habitat preferences of great bustard *Otis tarda* flocks in the arable steppes of central Spain: are potentially suitable areas unoccupied? Journal of Applied Ecology, 38, 193-203.

Larsen, J.K., Madsen, J. 2000. Effects of wind turbines and other physical elements on field utilization by pink-footed geese (*Anser brachyrhynchus*): A landscape perspective. Landscape Ecology, 15, 755-764. 67

Laurance, W.F., Croes, B.M., Tchignoumba, L., Lahm, S.A., Alonso, A., Lee, M.E., Campbell, P., Ondzeano, C. 2006. Impacts of roads and hunting on central African rainforest mammals. Conservation Biology, 20, 1251-1261.

Madsen, J. 1985. Impact of disturbance on field utilization of Pink-footed geese in West Jutland, Denmark. Biological Conservation, 33, 53-63.

Mahoney, S.P., Schaefer, J.A. 2002. Hydroelectric development and the disruption of migration in caribou. Biological Conservation, 107, 147-153.

Malcolm, J.R., Ray, J.C. 2000. Influence of timber extraction routes on Central African small-mammal communities, forest structure and tree diversity. Conservation Biology, 14, 1623-1638.

McLellan, B. N., Shackleton, D. M. 1989. Grizzly bear and resource extraction industries: habitat displacement in response to seismic exploration, timber harvesting and road maintenance. Journal of Applied Ecology, 26, 371-380.

Meunier, F.D., Verheyden, C., Jouventin, P. 1999. Bird communities of highway verges: influence of adjacent habitat and roadside management. Acta Oecologica, 20, 1-13.

Meunier, F.D., Verheyden, C., Jouventin, P. 2000. Use of roadsides by diurnal raptors in agricultural landscapes. Biological Conservation, 92, 291-298.

Nellemann, C., Cameron, R.D. 1996. Effects of petroleum development on terrain preferences of calving caribou. Arctic, 49, 23-28.

Nellemann, C., Vistnes, I. Jordhøy, P., Strand, O. 2001. Winter distribution of wild reindeer in relation to powerlines, roads and resorts. Biological Conservation, 101, 351-360. 69

Nellemann, C., Jordhøy, P., Vistnes, I., Strand, O., Newton, A. 2003a. Progressive impacts of piecemeal development. Biological Conservation, 113, 307–317.

Newmark, W.D., Boshe, J.I., Sariko, H.I., Makumbule, G.K. 1996. Effects of a highway on large mammals in Mikumi National Park, Tanzania. African Journal of Ecology, 34, 15-31.

Noel, L.E., Parker, F.R., Cronin, M.A. 2004. Caribou distribution near an oilfield road on Alaska’s North Slope, 1978-2001. Widlife Society Bulletin, 32, 757-771.

Oehler, J.D., Litvaitis, J.A. 1996. The role of spatial scale in understanding responses of medium-sized carnivores to forest fragmentation. Canadian Journal of Zoology, 74, 2070-2079.

Ortega, Y.K., Capen, D.E. 1999. Effects of forest roads on habitat quality for Ovenbirds in a forested landscape. Auk, 116, 937-946.

Paruk, J.D. 1987. Habitat utilization by bald eagles wintering along the Mississippi River. Transactions or the Illinois Academy of Science, 80, 333-342.

Piper, S.D., Catterall, C.P. 2006. Impacts of picnic areas on bird assemblages and nest predation activity within Australian eucalypt forests. Landscape and Urban Planning, 78, 251-262. 71

Reijnen, R., Foppen, R. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for Willow Warblers (*Phylloscopus trochilus*) breeding close to a highway. Journal of Applied Ecology, 31, 85-94.

Reijnen, R., Foppen, R., Ter Braak, C., Thissen, J. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. Journal of Applied Ecology, 32, 187-202. 72

Reijnen, R., Foppen, R., Meeuwsen, H. 1996. The effect of traffic on the density of breeding bird populations in Dutch agricultural grasslands. Biological Conservation, 75, 255-260.

Rheindt, F.E. 2003. The impact of roads on birds: Does song frequency play a role in determining susceptibility to noise pollution? Journal fur Ornithologie, 144, 295-306.

Rich, A.C., Dobkin, D.S., Niles, L.J. 1994. Defining forest fragmentation by corridor width: the influence of narrow forest-dividing corridors on forest-nesting birds in southern New Jersey. Conservation Biology, 8, 1109-1121.

Roedenbeck, I.A., Voser, P. 2008. Effects of roads on spatial distribution, abundance and mortality of brown hare (*Lepus europaeus*) in Switzerland. European Journal of Wildlife Research, 54, 425-437.

Rost, G.R., Bailey, J.A. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management, 43, 634-641.

Tigas, L.A., Van Vuren, D.H., Sauvajot, R.M. 2002. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. Biological Conservation, 108, 299-306.

Van der Zande, A.N., TerKeurs, W.J., van der Weijden, W.J. 1980. The impact of roads on the densities of four bird species in an open field habitat – evidence of a long-distance effect. Biological Conservation, 18, 299-321.

Van Dyke, F., Klein, W.C. 1996. Response of elk to installation of oil wells. Journal of Mammalogy, 77, 1028-1041.

Vistnes, I., Nellemann, C. 2001. Avoidance of cabins, roads, and power lines by reindeer during calving. Journal of Wildlife Management, 65, 915–925. 76

Yost, A.C., Wright, R.G. 2001. Moose, caribou and grizzly bear distribution in relation to road traffic in Denali National Park, Alaska. Arctic, 54, 41-48.