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Chapter 33

FLIGHT DOESN'T SOLVE EVERYTHING: MITIGATION OF ROAD IMPACTS ON BIRDS

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SUMMARY

Roads and traffic are typically more of a threat to the conservation of birds rather than a safety issue for motorists. Some bird species have biological features and life history traits that make them particularly vulnerable to habitat loss from roads and mortality due to wildlife-vehicle collisions (WVC). Road planning that proactively considers the biological needs of birds will help avoid project delays and extra costs for mitigation, as well as achieve positive outcomes for birds. Several strategies effectively avoid or mitigate the negative effects of roads on birds.

33.1 Roads can adversely affect birds despite the common assumption that birds avoid mortality and barrier effects because they can fly.

33.2 Wildlife-vehicle collisions kill millions of birds annually.

33.3 Planning the timing and location of road construction and maintenance is crucial for the survival and conservation of birds.

33.4 Flight diverters may reduce the likelihood of vehicle collisions with birds.

33.5 Wildlife crossing structures can decrease the barrier effect.

33.6 Structural changes along roads can reduce noise impacts.

33.7 Roadsides should be managed to make them less attractive to birds.

Implementing design features that separate birds from traffic, reducing resources that attract birds to the roadway and minimising disruptive light and noise emanating from the roadway are the main mitigation measures for birds. However, more research is needed to quantify the various effects of roads and the cumulative effect of road networks on birds and, perhaps more critically, to explore ways to prioritise and effectively mitigate the most negative impacts.

Handbook of Road Ecology, First Edition. Edited by Rodney van der Ree, Daniel J. Smith and Clara Grilo.

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INTRODUCTION

Human activities have caused hundreds of bird species to go extinct over the past five millennia (Pimm et al. 2006). Extinction risk is related to a suite of factors, the dominant ones being susceptibility to persecution, introduced predators and habitat loss. In the last three to four decades, the massive and expanding surface transportation network has become a new threat to many avian populations globally through habitat loss and direct mortality (Chapter 28). Fortunately, not all taxa are vulnerable to the effects of roads, and many of the responses are related to species-specific traits. Some basic themes apply for avoiding, minimising and mitigating impacts to birds when constructing a new road or when responding to a problem on an existing road. The aims of this chapter are to summarise the adverse effects caused by roads and traffic on bird populations and to suggest potential solutions.

LESSONS

33.1 Roads can adversely affect birds despite the common assumption that birds avoid mortality and barrier effects because they can fly

Birds are typically perceived as being able to avoid road impacts by flying away or flying higher than traffic. Innovative measures for reducing road impacts on birds have lagged behind those of other animal groups. This is probably because the problem is not fully understood nor considered a priority and perhaps also because, in the case of birds, mitigation is not always as conventional as providing standard measures, such as an underpass or a fence. Compared to the size of vehicles, birds are small and bird–vehicle collisions are not typically a safety concern for humans. There are exceptions, such as large birds of prey feeding on roadkilled carcasses which are unable to take off quickly enough to avoid collision. Road impacts to birds are species specific, so it is important to know which species occur near a road or proposed road to determine the impacts and appropriate mitigation measures.

Birds can avoid some impacts by flying above or away from vehicles. However, not all impacts can be readily avoided. Clearing of vegetation for road construction results in habitat loss and creates open areas that may fragment populations of forest-dwelling species (Reijnen et al. 1995). Roads may attract open-country or light-demanding species while causing other birds to avoid the area altogether (Benítez-López et al. 2010). Since birds rely heavily on acoustic communication, traffic noise is suspected to have a widespread indirect impact on many birds by reducing habitat use and, therefore, population size (Reijnen et al. 1995; Palomino & Carrascal 2007; McClure et al. 2013; Chapter 19; but see Summers et al. 2011). Kociolek et al. (2011) lists the negative effects of human-caused noise on avian community structure, breeding cycles, foraging, communication and brain response. Noise impacts to birds depend on the frequency and amplitude of the noise and of their species-specific calls and songs. While some bird species move away from noisy roads, several species are attracted to roadside verges with consequent high mortality rates due to WVC. Studies have shown that bird species with relatively high reproductive rates, high flight, small home range sizes and small body size are typically less vulnerable to road impacts (Rytwinski & Fahrig 2012; Chapter 28).

33.2 Wildlife-vehicle collisions kill millions of birds annually

WVC are estimated to kill 80 million birds annually in the United States, but true numbers may be an order of magnitude higher (Erickson et al. 2005). Species at high risk of WVC include those that hunt prey adjacent to roads (e.g. owls; Boves & Belthoff 2012, Fig. 33.1), scavenge road-killed carcasses (e.g. corvids, raptors), roost near roads (e.g. passerines) (Fig. 33.2), forage in roadside ditches or drainage retention ponds (e.g. wading birds) or nest near roads (e.g. some species of ground-dwelling birds). Grassland birds and waterfowl nesting in verges are vulnerable to WVC and to mowing practices that can directly kill eggs, fledglings and adults attending nests. Other factors may make birds particularly vulnerable to traffic. The typically low-flight behaviour of owls increases the risk of WVC (Fig. 33.1; Grilo et al. 2012), and the turbulence from passing vehicles can break bones and kill fragile birds (Orlowski & Seimbieda 2005). Vehicle headlights can also stun nocturnal species, leaving them vulnerable to WVC (Rich & Longcore 2006; Chapter 18). Moreover, lights can affect avian patterns of breeding, nestling maturation, singing and moulting (Molenaar et al. 2006). Artificial lighting can also mimic features of the night sky and attract migrating birds, increasing the likelihood of collision with structures (e.g. bridges, utility poles) (Chapter 18). Confusion from artificial lighting can increase flight time and deplete energy stores, thereby reducing body condition and making it more difficult to evade predators.

Birds are often attracted to the road and roadsides by fruit- and seed-bearing plants (Chapter 46), granular de-icing agents and roadway lighting. Vegetated medians enhance aesthetics and driver safety but

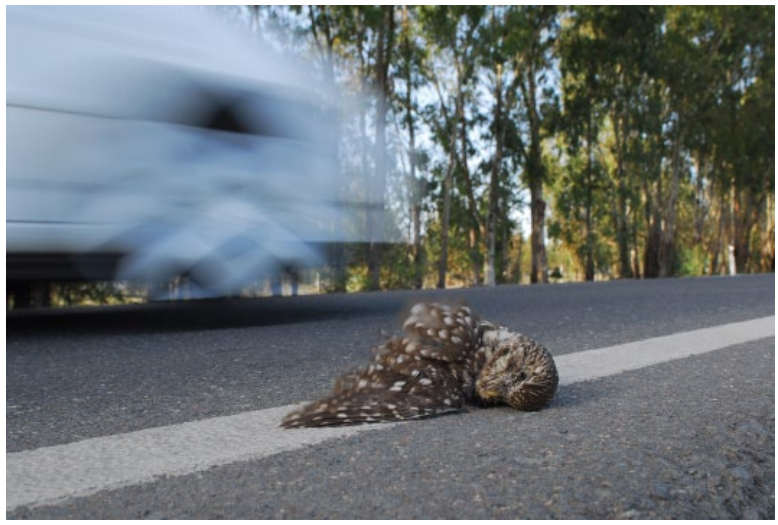

Figure 33.1 A little owl carcass on a national road in Portugal. Source: Photograph by and reproduced with permission from Joaquim Pedro Ferreira.

Figure 33.2 A Bullock's oriole carcass on a state highway in Idaho, United States. Source: A. Kociolek, Western Transportation Institute-Montana State University.

may increase the collision risk to birds because nutrient-rich food resources attract birds and their predators. Equally, mineral-rich de-icing salts increase collision risk because birds congregate on the road to ingest the salt to satisfy mineral deficiencies or to aid in grinding food. Ingesting road salt may also result in toxicity or death (Mineau & Brownlee 2005).

Road verges and medians of divided highways often have clear zones with mown grass or low vegetation to improve visibility and to provide space for drivers to recover if they lose control of their vehicles. These cleared areas may provide habitat and are often attractive to certain birds and other animals, typically including species that prefer edges. For example, hawks and

owls may hunt small mammals living in verges but in so doing increase their risk of WVC (Chapters 39 and 46).

33.3 Planning the timing and location of road construction and maintenance is crucial for the survival and conservation of birds

Birds are more vulnerable to disturbance at certain times of the year, such as during the breeding season when birds stake out their territories and young fledge and disperse. Migration periods are similarly important, when stopover habitats, which may be used only briefly, provide critical food resources for migrating species. It is important to avoid scheduling construction or maintenance activities during these times that may create visual threats, noise and dust and can harm or kill. Many species of ground nesting birds are affected by repeated disturbance, causing them to abandon their nests with eggs or young, and they are also at risk of being run over. Mowing costs can be reduced by modifying schedules to be less frequent or occur after the breeding season to protect nesting birds.

Identifying and protecting important habitat features can minimise the cumulative impact of WVC on birds. In general, the frequency of WVC with birds tends to be higher near waterbodies and watercourses (Erritzoe et al. 2003) because many bird species depend on these resources and are found in higher densities near water. Therefore, it is good practice to avoid planning new roads or widening existing roads near streams, rivers, lakes and bays, especially because there are few options to mitigate for WVC in these important habitats (Chapter 44). It is also important to avoid locating new roads or upgrading existing roads near other important habitat features (e.g. preferred roosting and nesting sites such as cliff walls or large old trees with hollows).

33.4 Flight diverters may reduce the likelihood of vehicle collisions with birds

Mitigation measures to reduce WVC with birds are not as widely developed or deployed as for larger animals, and research is needed to further develop effective approaches. Generally, mitigation measures to reduce WVC with ground birds will be similar to mitigation measures for larger, ground-based mammals, whereas measures to reduce mortality for flying birds will be similar to measures for bats (Chapter 34) and butterflies. Nevertheless, it is essential to consider the movement patterns of birds and their sensitivity to noise and light when designing roads.

Structural elements can encourage birds to fly above traffic or below the road through bridges or culverts. Flight diversion works best for species with direct, rapid flight rather than for those species with slower or meandering flight. Poles that produce an illusion of a solid barrier were effective in reducing bird roadkill in open coastal areas for royal terns and brown pelicans (Bard et al. 2002), and the concept would probably work in similar locations such as marshlands (Lesson 20.3). Flags or wider posts may also be effective. Fencing aimed at keeping large mammals off the road can serve as flight diverters for birds but can cause large, less manoeuvrable birds such as sage-grouse and Gambel's quail to die in fence collisions (Stevens 2011); flagging of the fence to increase visibility may help some species, but this needs to be tested (Fig. 20.2). No mitigation measures have been devised for species with low or erratic flight patterns, such as barn swallows, which are common roadkill casualties (Erritzoe et al. 2003).

Roads with soil berms that are higher than the road grade may encourage birds to fly up and over the road and traffic (Pons 2000; Grilo et al. 2012). Solid walls (e.g. Fig. 33.3) may also encourage birds to fly up and over the road and traffic, but further testing is required before it can be recommended as an effective approach. Importantly, the installation of these walls may result in bird-wall collisions, can increase the barrier effect for many other species of wildlife and can be aesthetically inappropriate in natural areas. (Pons 2000; Grilo et al. 2012). Similarly, tall trees next to the road may encourage higher flight for canopy-dwelling birds (e.g. Rosell & Velasco 2001) but may also increase the risk to species that live and fly closer to the ground in woody vegetation. Thus, consider adding fencing or walls on bridges adjacent to tall vegetation to encourage birds and bats to fly above traffic or under the bridge (Fig. 33.4). These walls may also double as sound and light walls, reducing penetration into adjacent areas (Figs 33.3 and 33.4).

Reducing the volume or speed of traffic will lessen impacts but are often logistically difficult to implement. Focusing traffic onto fewer high-volume roads rather than distributing vehicles over many roads is a strategic approach to conserve roadless or low-traffic areas (Jaarsma & Willems 2002; Chapter 3). This approach may require the closure of some roads and the upgrading or improvement of others. Lowering traffic speed may be warranted in places where population viability is a concern for at-risk species, such as ground-dwelling or nocturnal birds. Speed control is sometimes difficult to implement even for human safety reasons, but is

Figure 33.3 The elevated road plus 3–4 m tall solid walls along Peninsula Link in Victoria, Australia, may force some birds to fly up and over the traffic, avoiding WVC. However, the efficacy of this approach has not been evaluated, and this road and walls may be a barrier to movement for some species. Source: Photograph by Rodney van der Ree.

Figure 33.4 Fencing and walls on bridges can force birds to fly below the bridge or above the walls, hopefully avoiding traffic. In this example, in Australia, the coloured glass panels also act as sound and light walls. Walls of clear glass should be avoided to reduce the risk of bird-wall collision. Source: Photograph by Rodney van der Ree.

increasingly being adopted within protected areas (e.g. Jones 2000). Although some birds can reduce collision risk by adjusting their flight distances in response to vehicle speed (Legagneux & Ducatez 2013), there has been no systematic investigation of appropriate speeds to reduce WVC with birds of differing levels of mobility.

33.5 Wildlife crossing structures can decrease the barrier effect

Although most birds are physically capable of flying over roads, species vary in their willingness to cross roads. For example, some forest-dwelling species are

unlikely to cross gaps in forest cover greater than 50 m (Desrochers & Hannon 1997). Although typically designed for mammals, reptiles and amphibians, birds also benefit from wildlife overpasses and underpasses. Some bird species prefer to cross at these locations rather than over traffic (e.g. Jones & Bond 2010). Waterfowl have been recorded using drainage culverts as small as one metre in diameter across a four-lane highway (S. Jacobson, personal observations), although larger structures would likely service more species. In general, larger drainage structures that allow for natural streamflow are most desirable for more wildlife species (e.g. Fig. 45.4). Many species of birds have been recorded using underpasses, especially larger-diameter structures with streams (Foster & Humphrey 1995). Some ground-dwelling species such as quail and wild turkey may incorporate these structures into their traditional pathways if located appropriately (Smith & Noss 2011). Open-span bridges (Figs 21.1A, 33.4, 44.6 and 45.4) are likely to have higher rates of use by birds than enclosed culverts because they are more open and may be perceived as safer because birds tend to fly upwards when in danger. As with other species, crossing structures with more natural features are likely to be more acceptable to birds. There are currently no well-tested guidelines on designs or recommended dimensions of crossing structures for birds.

Some bridge and underpass structures provide nesting and roosting habitat for birds as diverse as peregrine falcons, guillemots, pigeons and swallows. Some artificial structures may have a net positive population effect for certain species that appear to avoid traffic by nesting on ledges above or below the bridge deck, although further research is required to confirm this for the wide range of species that use bridges (Fig. 33.5). Bridges can be difficult to maintain without disturbing nesting or roosting birds if maintenance is conducted at the same time that birds are nesting (Lesson 33.3). Some states in the United States have detailed maintenance plans to minimise this type of disturbance (Carey 2007).

33.6 Structural changes along roads can reduce noise impacts

Traffic noise can explain some declines in bird abundance (McClure et al. 2013). Several strategies can reduce road and vehicle noise (Chapter 19) so that birds can better utilise habitat adjacent to roads. That said, reducing the mortality of birds by minimising the attractiveness of roads and roadsides and forcing them to fly above traffic is also important to maintain bird populations (Summers et al. 2011). Reductions in noise levels can improve habitat use by birds as well as being appreciated by humans; and noise-absorbing road surfaces and modifying tyre designs may be the least expensive options. Solid wall sound barriers (Figs 33.3 and 33.4) can moderate noise, but it is important to ensure the design does not create a more significant barrier to wildlife movement or increase mortality through direct collision. Any structure that is not easily detectable, such as clear glass or certain

Figure 33.5 Ospreys frequently nest on bridge structures across rivers in northern coastal New South Wales, Australia (A), posing a traffic hazard and mortality risk to the birds. To alleviate this, artificial nesting platforms were erected at the highest point of bridges but suspended above the river (B). It soon became apparent that nesting by a threatened bird species could prevent maintenance during the breeding season, and nesting platforms are now erected on poles away from the bridge (C). Ospreys have successfully nested on many of these platforms and fledged young, allowing routine bridge maintenance to occur year-round. Source: Photographs by Kate Dallimore, Roads and Maritime Services, New South Wales.

types of netting that birds or bats collide with, should be avoided. Vegetation can absorb sound in direct proportion to its density, and dense plantings can reduce noise penetration. However, planting vegetation that is attractive to birds should be avoided as it may increase mortality rates. In contrast to Figs. 33.3 and 33.4 which show elevated roads, constructing the highway below grade or adding berms above grade can reduce sound travelling to adjacent habitats and provide some protection from WVC since birds may tend to fly higher over traffic. Long-term policy solutions include regulations for quieter vehicles, such as electric vehicles, and more effective mufflers. However, further research will be required to determine if the rate of WVC increases as vehicles become quieter potentially making it more difficult for birds to detect oncoming vehicles.

33.7 Roadsides should be managed to make them less attractive to birds

The best practice of bird conservation along roads is to avoid attracting birds to the road or roadside from the earliest planning stages. Roadsides and medians can be less of an attractant to birds if plant species that provide resources (e.g. food and nesting opportunities) are avoided. The attractiveness of the road and verge can be reduced by modifying the maintenance programme. Regularly mowing verges can reduce the attraction for some species and can be seasonally timed to avoid destroying nests. Under certain conditions (such as localised mortality hotspots of at-risk or high-profile species), it may be appropriate to reduce the attractiveness of the verge by converting it to gravel or other non-vegetative surface. Road sands and salts used as de-icing agents can be reduced through the use of ice-detecting technology or by using alternatives that are less attractive to birds (Lesson 33.2). Roadkilled carcasses, especially of larger-bodied animals that provide large quantities of food, should be promptly removed to avoid attracting scavenging birds. Artificial lighting should be avoided and reflective posts or reflectors embedded in the road surface are a low-cost alternative to identify road edges. Where lighting is required, use colours and designs that are less attractive for wildlife (e.g. blue/green lighting may be less attractive to nocturnally migrating birds; Poot et al. 2008; Chapter 18). Roadsides have multiple values and uses, and proposed management actions should be assessed against their potential impacts for other species and uses.

CONCLUSION

Every participant in road planning, construction and management can contribute to building a more sustainable road network and accounting for the biological needs of birds. Annually, hundreds of millions of birds die on roads globally; one way to reduce this loss is to separate birds from roads and traffic. Avoiding areas with high bird densities or rare and threatened species is the optimal approach to solving this problem. Strategically placed infrastructure, such as overpasses or flight diverters that encourage birds to fly higher than traffic or under bridges, provides opportunities for birds to safely traverse roads. Reducing resources that attract birds to the roadway is important to reduce collisions with foraging or nesting birds. Since artificial lighting and road noise can disturb birds well beyond the roadway, limiting their penetration can have positive benefits for birds as well as humans. More research is needed to quantify the various effects of road networks on birds (Guinard et al. 2012) and, perhaps more critically, to explore ways to prioritise and effectively mitigate the most negative impacts.

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FURTHER READING

Bujoczek et al. (2011): A study from Poland that compared body condition of birds killed by predators with birds killed by vehicle collision; roadkilled birds were in significantly better condition than those killed by raptors.

Fahrig and Rytwinski (2009): A review of the literature on the effects of roads and traffic on animal abundance and distribution revealing that birds showed mainly negative or no effects, with a few positive effects for some small birds and for vultures.

Jacobson (2005): A report outlining solutions to mitigate the negative effects of roads on birds, including crossing structures, flight diverters, modified mowing regimes, roadkill removal, appropriate median vegetation and modified de-icing agents.

Orłowski (2008): This paper shows that a disproportionately high mortality of birds was recorded near tree belts, hedgerows and built-up areas, while it was much lower in open farmland.

Parris and Schneider (2008): A study showing traffic noise hampered detection of song by conspecifics, making it more difficult for birds to establish and maintain territories and attract mates and possibly leading to reduced breeding success.

REFERENCES

Bard, A. M., H. T. Smith, E. D. Egensteiner, R. Mulholland, T. V. Harber, G. W. Heath, W. J. B. Miller and J. S. Weske. 2002. A simple structural method to reduce road-kills of royal terns at bridge sites. Wildlife Society Bulletin **30**: 603–605.

Benítez-López, A., R. Alkemade and P. A. Verweij. 2010. The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. Biological Conservation **143**: 1307–1316.

Boves, T. J. and J. R. Belthoff. 2012. Roadway mortality of barn owls in Idaho, USA. The Journal of Wildlife Management **76**: 1381–1392.

Bujoczek, M., M. Ciach and R. Yosef. 2011. Road-kills affect avian population quality. Biological Conservation **144**: 1033–1039.

Carey, M. 2007. Washington State Department of Transportation bridge maintenance and inspection guidance for protected terrestrial species. Pp. 246–248 in Proceedings of the 2007 International Conference on Ecology and Transportation. C. Leroy Irwin, D. Nelson and K. P. McDermott, editors. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Desrochers, A. and S. J. Hannon. 1997. Gap crossing decisions by forest songbirds during the post-fledging period. Conservation Biology **11**: 1204–1210.

Erickson, W. P., G. D. Johnson and D. P. Young Jr. 2005. A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.

Erritzoe, J., T. D. Mazgajski and T. Rejt, 2003. Bird casualties on European roads – a review. Acta Ornithologica **38**: 77–93.

Fahrig, L. and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society **14**(1): 21. http://www.ecologyandsociety.org/vol14/iss1/art21/ (accessed 29 September 2014).

Foster, M. L. and S. R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin **23**: 95–100.

Grilo, C., J. Sousa, F. Ascensão, H. Matos, I. Leitão, P. Pinheiro, M. Costa, J. Bernardo, D. Reto, R. Lourenço, M. Santos-Reis and E. Revilla. 2012. Individual spatial responses towards roads: implications for mortality risk. PLoS One. **7**: e43811. http://dx.plos.org/10.1371/journal.pone.0043811 (accessed 29 September 2014).

Guinard, E., J. Romain and C. Barbraud. 2012. Motorways and bird traffic casualties: carcasses surveys and scavenging bias. Biological Conservation **147**: 40–52.

Jaarsma, C. F. and G. P. A. Willems. 2002. Reducing habitat fragmentation by minor rural roads through traffic calming. Landscape and Urban Planning **58**: 125–135.

Jacobson, S. 2005. Mitigation measures for highway-caused impacts to birds. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.

Jones, M. E. 2000. Road upgrade, road mortality, and remedial measures: impacts on a population of eastern quolls and Tasmanian devils. Wildlife Research **27**: 289–296.

Jones, D. N. and A. R. F. Bond. 2010. Road barrier effect on small birds removed by overpasses in South East Queensland. Ecological Management & Restoration **11**: 65–67.

Kociolek, A., A. P. Clevenger, C. C. St Clair and S. Proppe. 2011. Effects of road networks on bird populations. Conservation Biology **25**: 241–249.

Legagneux, P. and S. Ducatez. 2013. European birds adjust their flight initiation distance to road speed limits. Biology Letters **9**(5): 20130417.

McClure, C. J. W., H. E. Ware, J. Carlisle, G. Kaltenecker and J. R. Barber. 2013. An experimental investigation into the effects of traffic noise on distributions of birds: avoiding the phantom road. Proceedings of the Royal Society B **280**: 20132290. http://dx.doi.org/10.1098/rspb.2013.2290 (accessed 29 September 2014).

Mineau, P. and L. Brownlee. 2005. Road salts and wildlife – an assessment of the risk with particular emphasis on winter finch mortality. Wildlife Society Bulletin **33**: 835–841.

Molenaar, J. G. de, M. E. Sanders and D. A. Jonkers. 2006. Roadway lighting and grassland birds: local influence of road lighting on a black-tailed godwit population. Pp. 114–136 in Ecological consequences of artificial night lighting. C. Rich and T. Longcore, editors. Island Press, Washington, DC.

Orłowski, G. 2008. Roadside hedgerows and trees as factors increasing road mortality of birds: implications for management of roadside vegetation in rural landscapes. Landscape and Urban Planning **86**: 153–161.

Orlowski, G. and J. Siembieda. 2005. Skeletal injuries of passerines caused by road traffic. Acta Ornithologica **40**: 15–19.

Palomino, D. and L. M. Carrascal. 2007. Threshold distances to nearby cities and roads influence the bird community of a mosaic landscape. Biological Conservation **140**: 100–109.

Parris, K. M. and A. Schneider. 2008. Impacts of traffic noise and traffic volume on birds of roadside habitats. Ecology and Society **14**(1): 29. http://www.ecologyandsociety.org/vol14/iss1/art29/ (accessed 29 September 2014).

Pimm, S. L., P. Raven, A. Peterson, C. H. Sekercioglu and P. R. Ehrlich. 2006. Human impacts on the rates of recent, present, and future bird extinctions. Proceedings of the National Academy of Sciences of the United States of America **103**: 10941–10946.

Pons, P., 2000. Height of road embankment affects probability of traffic collision by birds. Bird Study **47**: 122–125.

Poot, H., B. J. Ens, H. de Vries, M. A. H. Donners, M. R. Wernand and J. M. Marquenie. 2008. Green light for nocturnally migrating birds. Ecology and Society **13**: 47. http://www.

ecologyandsociety.org/vol13/iss2/art47/ (accessed 29 September 2014).

Reijnen, R., R. Foppen, C. ter Braak and J. Thissen. 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.

Rich, C. and T. Longcore. 2006. Ecological consequences of artificial night lighting. Island Press, Washington, DC.

Rosell, C. and J. Velasco. 2001. Manual de prevenció i correcció dels impactes de les infraestrutures viàries sobre la fauna – Documents dels Quaderns de medi ambient, no 4; 2a edição. Generalitat de Catalunya Departament de Medi Ambient. Catalunya.

Rytwinski, T. and L. Fahrig. 2012. Do species life history traits explain population responses to roads? A meta-analysis. Biological Conservation **147**: 87–98.

Smith, D. J. and R. F. Noss. 2011. A reconnaissance study of actual and potential wildlife crossing structures in Central Florida, Final report. UCF-FDOT Contract No. BDB-10. 154 pp. + appendices.

Stevens, B. S. 2011. Impacts of fences on greater sage-grouse in Idaho: collision, mitigation, and spatial ecology. Thesis, University of Idaho, Moscow.

Summers, P., G. M. Cunnington and L. Fahrig. 2011. Are the negative effects of roads on breeding birds caused by traffic noise? Journal of Applied Ecology **48**: 1527–1534.