Effects of Paved Roads on Birds: A Literature Review and Recommendations for the Yellowstone to Yukon Ecoregion

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Birds have a high diversity of niches and serve as valuable indicators of environmental conditions. Downward population trends around the globe are cause for concern (Birdlife International 2008a). In North America, at least 20 species previously catalogued as common appear to have lost more than 50 percent of their continental population. Further, more than half of neotropical migrant species populations have declined in the past four decades. The reasons for this decline are not fully understood (Butcher and Niven 2007, Birdlife International 2008b, Birdlife International 2008c).

Paved roads are a pervasive feature on the landscape and their ecological effects on vertebrate wildlife have been well documented (Forman and Alexander 1998, Spellerberg 1998, Forman and Deblinger 2000, Trombulak and Frissell 2000). In this review, we drew from these works and others to bring attention to paved-road-related threats, specifically to bird populations. A mitigation-centered report by Jacobson (2005) was the single report we found that summarized all the recognized direct and indirect ecological impacts of paved highways specifically to birds. Erritzoe et al. (2003) provided avian casualty estimates and included a meta-analysis of contributing factors of road mortality based mostly on European studies. Erickson et al. (2005) offered U.S. avian–vehicle collision estimates. De Molenaar et al. (2006) reported on the understudied effects of roadway lighting on bird populations. Reijnen and Foppen (2006) provided a thorough review of what is increasingly becoming the most recognized direct impact on breeding bird populations—*traffic*. Lastly, Slabberkoorn and Ripmeester (2008) detailed the ways birds can be affected by one of the most far-reaching road emissions—*traffic noise*.

The Yellowstone to Yukon (Y2Y) ecoregion is one the few areas in North America that continues to support the complete suite of wildlife species that existed prior to European settlement (Chadwick and Gehman 2000). The Yellowstone to Yukon Conservation Initiative Society has developed an avian conservation strategy that uses 20 focal species to represent the needs of 109 species of concern in the region (Pearce et al. 2008). Data were obtained on bird distributions and were used to identify avian biodiversity hotspots and habitat associations of focal species (Pearce et al. 2008). Numerous and a growing number of roads bisect the areas that Pearce et al. (2008) identified as key to conserving avian biodiversity in the Y2Y ecoregion. A review of the scientific literature on road effects on birds would serve as an important first step in identifying the current threats in the Y2Y ecoregion, and help prioritize research to better understand and mitigate the impacts.

The purpose of this literature review is threefold: 1) to gain a better understanding of the breadth of paved-road-related threats to birds, 2) to synthesize literature that will aid in heightening awareness about surface transportation threats to birds, and 3) to help prioritize research in order to further bird conservation efforts within the Y2Y ecoregion.

2. METHODOLOGY

We conducted a literature search through Biological Abstracts and Web of Science, Proceedings of the International Conference on Ecology and Transportation (Irwin et al. 2003, 2006, 2007), and Google Web and Scholar, as well as relevant ecological and avian journals directly. We searched for bird(s), avian, and avifauna with any of the following additional terms: paved, road, highway, motorway, transport, vehicle, auto, traffic, collision, roadkill, mortality, breeding, success, density, abundance, barrier, fragmentation, disturbance, effect, impact, mitigation. The cumulative large-scale effect of habitat loss, fragmentation, non-native species invasions and climate change undoubtedly takes its toll on bird populations and may be better addressed within the context of urbanization as a whole. This paper focuses more on the scale of individual paved roads.

In order not to replicate previous works, we attempted to include sources that 1) were not covered in other reviews unless they provide useful background information for the reader not acquainted with the literature, 2) state a known or potential impact on the population or species level, or 3) offer insight on contributing factors. To enhance readability, we provide scientific bird species names in Appendix A.

3. LITERATURE REVIEW

3.1. Overview of ecological effects of paved roads on birds

The International Union for Conservation of Nature (IUCN) includes roads and railroads in its list of threats to certain birds and other wildlife (IUCN 2008). Road construction and road density can lead to significant loss of biodiversity at local (Burton et al. 2002), regional and landscape scales, the full effect of which may not be detected for decades (Findlay and Houlahan 1997, Findlay and Bourges 2000). Reduced breeding success has been correlated to road proximity or road density for species ranging from warblers to vultures (Catchpole and Phillips 1992, Donazar et al. 1993). Bird community integrity has been shown to be strongly correlated to roadless areas (Glennon and Porter 2005). However, positive effects from paved roads on certain bird species have also been identified. For example, the warmth of blacktop can reduce metabolic expenditures, bridges serve as nesting sites, roadsides function as habitat, and road-killed carrion is a food source (Whitford 1985, White and Tanner-White 1988, Knight and Kawashima 1993, Meunier et al. 1999, Forman 2000, Reijnen and Foppen 2006, Huijser and Clevenger 2006). Revegetated rights-of-way can serve as habitat linkages for some species, but fragmentation-sensitive species appear to require remnant habitat strips (Bolger et al. 2001). Indeed, the clearing of remnant native vegetation along roadsides in agricultural areas can result in reduced species richness and abundance (Fulton et al. 2008).

While the most obvious threat of paved roads to individual birds is injury or mortality due to vehicle collisions, this is often considered less compelling when compared to the more insidious effects of roads, such as behavior modification or decreased population density, diversity, and/or breeding success (Reijnen and Foppen 1994, Forman and Alexander 1998, Jacobson 2005, Ramp et al. 2006, Reijnen and Foppen 2006). However, in some cases, direct road mortality is the major threat to a population (Mumme et al. 2000, Ramsden 2003, Reijnen and Foppen 2006). Given the vast network of roads in combination with other persistent anthropogenic factors at work (e.g., habitat loss, fragmentation, non-native species invasions, climate change), the potential impact of road mortality on specific wildlife populations should not be dismissed (Erritzoe et al. 2003, Glista et al. 2008).

Many studies report that certain species of birds avoid roads, paved or otherwise, when selecting habitat during some part of their life cycle (Ferrer and Harte 1997, Parrish et al. 2001, Sara and DiVittorio 2003, Bollinger and Gavin 2004, Arcos and Salvadores 2005, Balbontin 2005, Carrascal et al. 2006, Gavashelishvili and McGrady 2006). The risk of nest abandonment can also increase near roads (Gorog et al. 2005). In an extreme case, Great Bustard populations in Portugal appear to be concentrating themselves geographically, with new road building responsible for three of the local population declines (Pinto et al. 2005). Long-term trends suggest the Portuguese population may ultimately become confined to a single high quality site, thereby increasing probability of extinction (Pinto et al. 2005). For those species which use roadways as habitat, maintenance activities to roads and ditches can inadvertently destroy nests, a particular concern for declining species such as the Burrowing Owl (Catlin and Rosenberg 2006).

Road-related threats to bird populations deserve more attention, however, conservation or mitigation action is often considered to be warranted only after a population-level decline can be demonstrated (Reijnen and Foppen 2006). Many road-related bird studies are conducted in or adjacent to protected areas, illustrating there may be no panacea that escapes road-related impacts (Reijnen and Foppen 1994, Bard et al. 2002, Gutzwiller and Barrow 2003, Clevenger et al. 2003, Frey and Conover 2006, Ramp et al. 2006).

3.2. Disturbance

3.2.1. Avoidance response to traffic

Traffic volume is believed to be the most important factor affecting breeding bird population densities near roads (Reijnen and Foppen 2006). Traffic can influence occupancy levels (Clec'h 2001) and create avoidance zones that extend as far as 1000 m or more from the road itself (Reijnen and Foppen 2006). The density-depressing effect phenomenon is widespread among birds, as roughly 55 percent of species studied in different taxonomic groups across different habitat types appear to be affected (Reijnen and Foppen 2006). This implies that not all bird species densities respond negatively to traffic (Kaseloo 2005, Reijnen and Foppen 2006). For those that are negatively affected, however, population losses within avoidance zones can range from 30 percent to almost 100 percent (Reijnen and Foppen 2006).

The number of affected species increases with traffic volume but the relationship appears to reach threshold at an average daily traffic volume of 30,000 vehicles a day (Reijnen and Foppen 2006). Traffic volumes as low as 5,000 vehicles per day still result in the population density-depressing effect although the number of species affected is fewer and the effect-distances are much lower (Reijnen and Foppen 2006). Generally speaking, roads with 50,000 vehicles per day can result in an effect-distance of ~800 m for woodland species and more than 900 m for grassland species (Reijnen and Foppen 2006). Open habitats appear more prone to this detrimental effect than closed habitat types and may help explain the decline in grassland birds over the past few decades (van der Zande et al. 1980, Forman et al. 2002). Traffic volume alone may not fully explain reduced passerine population densities near road networks in some situations where habitat fragmentation, edge effects, and changes in community structure may also be playing a role (Ingelfinger and Anderson 2004).

Perhaps the most important contribution to the current knowledge of traffic impacts on birds was research conducted in The Netherlands (Reijnen and Foppen 1994, Foppen and Reijnen 1994). The authors found that the density of male Willow Warblers was lower in the road zone (0–200 m from the road) than in similar habitat farther from the road (Reijnen and Foppen 1994, Foppen and Reijnen 1994). The mechanism in these roadside territories seemed to be that males experienced difficulty in attracting and/or retaining mates because females would abandon the road zone, possibly due to territorial song being impeded by traffic noise (Reijnen and Foppen 1994). For those males that could attract a mate, breeding success was not different between roadside and control areas but the total reproductive output per capita in roadside territories was lower (Reijnen and Foppen 1994). The following year, unmated males would disperse to new territories farther from the road and inexperienced males would take their place via immigration, illustrating that roadside territories acted as habitat sinks (Foppen and Reijnen 1994).

In a separate study, Pied Flycatcher fledgling survival was reduced near roads, possibly a result of parent mortality from roads (Kuitunen et al. 2003). Similar to the ecological trap theory of passerines being attracted to edge habitats where predation activity is higher, in this case predation is vehicle traffic (Gates and Gysel 1978 in Kuitunen et al. 2003).

There may also be a temporal effect from traffic. In Spain, two species of vulture and Spanish Imperial Eagles were seen less often on weekend days (Saturday and Sunday) when traffic volume was higher (Bautista et al. 2004). While the exact mechanism for the raptors' weekly cycle of appearance remains unknown, human activities, possibly increased weekend traffic, is believed to play a role (Bautista et al. 2004).

3.2.2. Traffic noise

There are multiple emissions from highway traffic that might explain its density-depressing effect, including pollution, roadkills, visual disturbance, and mechanical vibration, but traffic noise is probably the most influential at larger distances (van der Zande et al. 1980, Forman et al. 2002, Reijnen and Foppen 2006). While traffic noise is suspected to be the major cause for decreased breeding bird diversity and density near roads, there may be confounding factors such as edge effects (Habib et al. 2007). Direct evidence that chronic anthropogenic noise negatively impacts bird populations is lacking but there is increasing evidence (Habib et al. 2007, Slabberkoorn and Ripmeester 2008).

In a recent study that isolated chronic industrial noise from other potential confounding variables, Ovenbird pairing success and age structure were affected by chronic noise (Habib et al. 2007). It is hypothesized that background noise interferes with song amplitude and/or quality such that females may avoid or not hear males in habitats with high noise levels (Habib et al. 2007). Results from this industrial noise study provide support for road avoidance studies that concluded chronic noise negatively influences habitat quality and the breeding activities of certain bird populations (Habib et al. 2007).

Anthropogenic noise, including traffic noise, can affect songbird breeding opportunities and territory distribution if the frequency is within the same range as, or masks, territorial songs (Weiserbs and Jacob 2002, Rheindt 2003, Habib et al. 2007, Slabbekoorn and Ripmeester 2008). Faint high-pitched bird songs can also be drowned out by traffic noise amplitude (Slabberkoorn and Ripmeester 2008). Traffic noise may have been responsible for the local disappearance of sensitive species in Belgium (Weiserbs and Jacob 2002).

Some songbird species are able to raise their song frequency to prevent overlap with low-frequency traffic noise, to increase amplitude to be heard above the ambient noise level, or to adjust their singing schedule to avoid competing with high traffic periods (Slabberkoorn and Peet 2003, Slabberkoorn and den Boer-Visser 2006, Fuller et al. 2007, Slabberkoorn and Ripmeester 2008). Other species appear less able to adapt their songs, and even birds with relatively high amplitude songs are shown to experience reduced pairing success (Habib et al. 2007). Whether a particular species is vulnerable to the masking effect of noise can depend on the frequencies or amplitude of its songs and/or the plasticity of its songs (Lengagne 2008, Slabberkoorn and Ripmeester 2008).

In an experimental study, domestic chicks exposed to recorded traffic noise had lower mean body weights over the course of twenty weeks and then had a lower average rate of egg laying than controls (Abe and Sugawara 1986). Traffic noise may also cause changes in feeding behavior, such as increased visual scanning for predators, since auditory cues are masked by ambient noise when birds would otherwise be feeding (Slabbekoorn and Ripmeester 2008). Quiet call notes between mates or chick begging calls can be impeded by traffic noise (Habib et al. 2007). Ambient noise can also mask communication intended for conspecifics to minimize competition (Slabbekoorn and Ripmeester 2008). If communication is impaired, then individual fitness, survival rates, reproductive success or viability of a population can be affected (Habib et al. 2007, Slabbekoorn and Ripmeester 2008).

In short, traffic volume and associated noise can affect certain breeding bird densities in woodland and grassland habitats near roads (Kaseloo 2005). Slabberkoorn and Ripmeester (2008) list mitigation measures (e.g., physical noise barriers and temporal adjustments to traffic flow) that may help abate noise for the benefit of humans and birds. Experimentation using willow hedges (*Salix* sp.) as sound-attenuating measures is encouraging (Labrecque and Teodorescu 2005). However, the true benefits of this type of noise reduction measure are unknown as they may attract birds to highways. Data remains insufficient to guide conservation/mitigation efforts in detail (Slabberkoorn and Ripmeester 2008) but noise-suppressing measures may be able to effectively mitigate the impact of noise on birds (Reijnen and Foppen 2006).

3.2.3. Roadway lighting

Artificial lighting can affect avian biorhythms with regard to development, singing patterns, breeding, molting, migration (De Molenaar et al. 2006) and possibly other activities. There is some evidence that roadway lighting may exert a negative effect on habitat quality and the timing of breeding for the Black-tailed Godwit, an indicator species for open grassland birds in Afro-Eurasia (De Molenaar et al. 2006).

Lights on gas production platforms in the North Sea have been documented to attract thousands of migrating songbirds, waders, ducks and owls on cloudy nights (van de Laar 2007). As a result, many of these birds wasted energy while circling platforms where they were at increased risk of predation and collision (van de Laar 2007). In an attempt to mitigate the number of birds adversely affected from continuously circling the platforms, a Dutch study found that installing green lights drastically reduced the impact to birds while maintaining safe working conditions (van de Laar 2007). Such bird-friendly lighting has the potential to be used in highway situations (Poot et al. 2008). Despite the limited experimental data available for effects of roadway lighting, specifically, The Netherlands has instituted policy that minimizes light sources for the benefit of breeding birds while saving energy and ensuring traffic safety (De Molenaar et al. 2006).

3.3. Mortality

3.3.1. Bird–vehicle collisions

Magnitude and nature of the problem

In transportation research, mitigation-based road mortality studies have typically focused on vehicle collisions involving deer and other large-bodied animals, emphasizing impacts to human safety and monetary loss (Huijser et al. 2007). It has become increasingly apparent, however, that small- to medium-sized vertebrates representing a variety of taxa deserve attention with regard to the population-level impacts of vehicle-caused mortality (Fahrig et al. 1995, Mumme et al. 2000, Ramsden 2003, Clevenger et al. 2003, Huijser et al. 2007, Boves 2007, Glista et al. 2008).

Biologists have attempted for decades to document and/or estimate the number of roadkills (Stoner 1925, Schlumpf 1940). Each year, millions of birds die directly from anthropogenic causes in the United States alone, with vehicles accounting for approximately 8.5 percent (80 million fatalities) (Erickson et al. 2005). Due to difficulties with searcher efficiency, scavenger bias (Erickson et al. 2005, Boves 2007) or cause of death determination (Kerlinger and Lein 1988), this estimate remains an underestimation of the actual number of birds killed on U.S. roads (Erickson et al. 2005). The true number may be an order of magnitude higher (Erickson et al. 2005). Even long-term studies of 100 percent marked individuals can result in underestimates of road mortality (Mumme et al. 2000). Alternatively, the relative importance of road mortality may be overstated if only carcasses are studied (Hernandez 1988, Aebischer et al. 2005). Vehicle collisions may also cause non-fatal injuries that prevent flight and, consequently, leave birds vulnerable to another cause of death (Orlowski and Siembieda 2005). Collisions with linear features such as power lines account for a major source of bird mortality (Erickson et al. 2005) and photo documentation exists for raptors that have died by getting their talons stuck on sign posts.

Several studies have shown that roads may not function as barriers to bird movements (Malizia et al. 1998, St. Clair 2003, Gopi Sundar 2004), but rather that the willingness of birds to cross well-travelled roads creates opportunity for vehicle collision (St. Clair 2003, Gopi Sundar 2004). That some birds are more likely to cross highways than rivers illustrates that certain species may not perceive vehicles as a risk (St. Clair 2003). Some species, such as the Florida Scrub-Jay in the Corvid family, may have the ability to learn to avoid vehicles (Mumme et al. 2000). Others, such as nocturnal species that fly low or that can be stunned by headlights, might not get the opportunity to learn to avoid vehicles (Loos and Kerlinger 1993, Jackson 2002). Natural selection over time might result in individuals that avoid roads and/or vehicles and decrease the overall likelihood of being struck (Mumme et al. 2000, Jackson 2003a).

Affected species or groups

Some taxa of North American birds appear to be more at risk from road mortality than others. Some birds of prey, Barn Owls, in particular, are especially vulnerable to vehicle collision due to their low flight and hunting behavior and have suffered heavy losses (Seiler 2003, Ramsden 2003, Reijnen and Foppen 2006, Boves 2007). Accounting for removal and search bias, an Idaho study estimated an overall adjusted mortality rate of 288–599 Barn Owls struck per 100 km/year (Boves 2007). Walking birds, water birds, ground nesters, scavengers, frugivores, winter ground seed eaters and migrants that make land fall after traversing long distances over open water are also considered vulnerable (Jacobson 2005). Omnivores, too, can be more susceptible when compared to other feeding guilds (Gopi Sundar 2004) especially if they are localized habitat specialists (Mumme et al. 2000). However, a recent Canadian study concluded that ground nesters, aerial insectivores, residents and low flying birds are not particularly at risk (In prep, Longmore et al.). The study found that scavengers and birds with high wing loading (or low agility) were more vulnerable to being struck (In prep, Longmore et al.). Lower agility due to higher weight might explain why female Barn Owls suffer higher levels of road mortality compared to males, which on average have only 82 percent of the body mass of females (Boves 2007).

Despite the high number of bird mortalities from vehicles each year, few references named road mortality as a major cause for a bird population or species decline in North America: 1) Florida

Scrub-Jay (Mumme et al. 2000, IUCN 2008); 2) Audubon's Crested Caracara; and 3) Hawaiian Goose (IUCN 2008). A possible reason is that, in general, juveniles tend to be the victims of road mortality, thus, having less of an effect on overall population size (Reijnen and Foppen 2006).

Vehicle collision as one source of mortality in any given sustainable population may not elicit immediate conservation concern, however, it is believed that road mortality can impact small, isolated, declining, threatened or endangered populations or species (Mumme et al. 2000, Ramsden 2003, Clancy 2004, Kofron and Chapman 2006, Glista et al. 2008). Investigating the demographic effects of, or mitigating, road mortality prior to any official change in conservation classification is worthwhile (Fajardo 2001, Jackson 2002; Clancy 2004; Orlowski 2005, Boves 2007). The same can be said for considering road mortality rates in or near conservation areas slated for road expansion (Ascensao 2005, Gryz and Krauze 2008). It should be noted, however, in the case of the Florida Scrub-Jay, Audubon's Crested Caracara, and Hawaiian Goose, a substantial reduction in vehicle collisions may not automatically result in viable populations because of other factors such as habitat loss (Huijser et al. 2007).

Contributing factors of bird–vehicle collisions and possible mitigations

Whether the road environment is used by wildlife appears to be species-specific, with some species being attracted and others repelled (Ramp et al. 2006). Species abundance along roads may be positively correlated with road casualties (Fulton et al. 2008). It seems logical that those species involved in vehicle collisions are those that actually use the road environment, although the likelihood of species susceptibility depends on taxonomic and landscape characteristics (Clevenger et al. 2003, Ascensao 2005, Ramp et al. 2006, In prep, Longmore et al.). In a recent Canadian study, only 22 percent of birds detected in point counts (conducted ~50 m from the road) were also found road-killed (In prep, Longmore et al.). Previous work has shown that wildlife roadkill aggregations are not randomly distributed and instead tend to be clustered, at least in part, due to specific habitat or land use patterns (Clevenger et al. 2003, Ascensao 2005). Several biotic and road-related factors appear to be correlated with an increased frequency of avian roadkills.

The question remains whether a basic set of best management practices exists for mitigating bird road mortality. Before particular roadkill mitigations can be employed, relatively precise locations of roadkill aggregations must first be identified along with specific details on road design and adjacent habitat (Clevenger et al. 2003, Ramp et al. 2006). It has been suggested that roadkill risk can be determined by a combined analysis of bird behavior and habitat types (Varga et al. 2005). Species' wing loading information may also help better predict areas of high-risk for bird–vehicle collisions.

Seasonality or activity periods

Most bird roadkills tend to occur between early spring and early fall (Hernandez 1988, Tsutsubuchi et al. 1999, Erritzoe et al. 2003, Clevenger et al. 2003, Fulton et al. 2008), however some studies did not include winter surveys. The spring to fall seasonal roadkill pattern may be associated with breeding and/or dispersal of inexperienced juveniles (Hernandez 1988, Clevenger et al. 2003, Hell et al. 2005, Fulton et al. 2008, Gryz and Krause 2008). In the case of Idaho Barn Owls, however, roadway mortality peaked in winter, which coincides with natal dispersal and the need to hunt more often to avoid freezing or starvation (Boves 2007). Consistent raptor roadkills have also been documented on a migration route and wintering grounds in late fall/winter (Loos and Kerlinger 1993). In India, birds were more often road-killed during the wet monsoon season compared to other seasons of the year (Gopi Sundar 2004). This is in contrast to Europe where most mortality occurs in dry months (Erritzoe et al. 2003). Seasonal differences in bird roadkill frequency are not always observed, as is the case in areas like subtropical Florida, which lacks seasonality (Main and Allen 2002, Smith and Dodd 2003). Passerines do not appear to be at particular risk during migration when they have been observed flying at a safe height; rather, risk is incurred during daily activities before and after migration (Varga et al. 2005). Seabirds forced inland by tropical storms become vulnerable to vehicle collisions if storms occur early enough in the season when juveniles are still dependent on adults for food (McNair 1998).

Resource availability or attractants

Species-specific behavior in response to the road environment is likely to influence the risk of vehicle collision (Erritzoe et al. 2003). Some species utilize roads and rights-of-way for foraging, hunting, scavenging, shelter or nesting, which can increase their vulnerability to vehicle collision (Jackson 2003a, Orlowski 2005, Huijser et al. 2007, Boves 2007, Fulton et al. 2008). Breeding birds may not perceive roaded habitats as inferior even though they may be acting as a habitat sink or ecological trap (Mumme et al. 2000, Boves 2007). There is a greater propensity for birds to cross narrow gaps to access forested medians, but this increases their vulnerability to collisions with vehicles (Clevenger et al. 2003). The likelihood of being killed by a vehicle appears to increase in the presence of roadside trees and hedgerows (Erritzoe et al. 2003, Orlowski 2005). To some degree, this counters evidence that taller roadside vegetation reduces the frequency of avian roadkills (Ramp et al. 2006) but it may be an issue of scale. Bird roadkills also appear correlated to watercourses (Erritzoe et al. 2003, Ascensao 2005) and houses (Ascensao 2005). Lights, which attract insects, may explain the attraction of certain birds to roadways making them more vulnerable to collision (Jackson 2003b). However, higher roadkills have also been found on non-illuminated versus illuminated roads (Hernandez 1988). A possible explanation for finding more road-killed ground-dwelling African Nightjars on a paved versus an unpaved road is that gravel roads are too noisy for predators (Jackson 2003b). Some birds are attracted to road-killed conspecifics (Orlowski 2004).

Habitat type and structure

There is evidence that birds are more likely to be road-killed at lower elevations (Clevenger et al. 2003) and in relatively open or low-growing habitats than forested habitats (Hernandez 1988, Clevenger et al. 2003, Ascensao 2005, Ramp et al. 2006). Taller roadside vegetation appeared to reduce the frequency of avian roadkills (Ramp et al. 2006). However, three-lane roads surrounded by dense tree cover, in comparison to two- or four-lane roads, have been associated with a higher relative number of road-killed canopy-dependent species (Taylor and Goldingay 2004). A proposed mitigation to reduce bird road mortalities on busy divided highways is to provide forest cover in medians (Bélisle and St. Clair 2001).

Traffic speed and volume

While traffic speed and volume are often named as contributing factors of road-related mortalities (Trombulak and Frissell 2000), it can be difficult to ascertain the direction of their influence (Erritzoe et al. 2003). Higher incidences of bird roadkills are not necessarily correlated with an increase in traffic volume (Lode 2000, Knight et al. 1995). High traffic volume roads can have a repelling or avoidance effect on wildlife (Seiler 2003, Clevenger et al. 2003). Studies indicate that roads with low to moderate traffic volume but high speeds incur a higher rate of vertebrate roadkills (Clevenger et al. 2003, Ramp et al. 2006). Possibly the simplest and most cost-effective mitigation for reducing bird road mortality would be to reduce traffic speed to allow birds time to avoid oncoming traffic (In prep, Longmore et al.). However, even very slow speeds in protected areas can result in nocturnal bird roadkills (Jackson 2002) even though such collisions can be avoided (Jackson 2003a). Warning signs to encourage slower vehicle speeds are sometimes recommended (Kofron and Chapman 2006) but have not been shown to be effective in reducing road mortality (Huijser et al. 2007). It can also be difficult to quantify carcasses that are displaced from the roadway during high speed collisions (Erritzoe et al. 2003). In Europe, birds tend to be road-killed in greater numbers on weekends and holidays, possibly due to the lack of peaks in morning and evening traffic (Erritzoe et al. 2003).

Road features

The probability of collision has been shown to increase as adjacent road embankment height decreases (Pons 2000). When comparing elevated sections to grade-level sections in forested habitat, bird roadkills have been found to be higher on grade-level sections (Clevenger et al. 2003). Conversely, in farmland, more bird roadkills were found on elevated compared to grade-level sections but most of these were flightless hens that walked up embankments with limited visibility (Taylor and Mooney 1991). Pole-like vertical barriers that force birds to fly higher than the road surface of a marine causeway have proven effective in reducing the frequency of Royal Tern and other seabird roadkills (Bard et al. 2002) with a net annual economic benefit (Shwiff et al. 2003). Similar mitigations have been recommended for songbirds (Orlowski 2005). An experimental study of bird-protection walls did not reduce and actually contributed to the number of roadkills (Varga et al. 2005). Given that paved roads are a pervasive feature across much of the continent (Forman et al. 2003, National Research Council 2005), mitigations that minimize direct conflicts between birds and vehicles are of interest (Jacobson 2005, Glista et al. 2009).

3.3.2. Other potential sources of road-related mortality

Contaminants

Deicers, petroleum-related organic compounds, nutrients, sediments, agricultural chemicals, *et cetera*, are regularly released from the paved road network during construction, maintenance and use (Buckler et al. 1999). Runoff constituents and their mixtures have the potential for biological effects in birds and other biological endpoints, which may, in turn, affect productivity and diversity of biological communities (Buckler et al. 1999). Keeping roads unpaved does not necessarily avoid potential contamination since unpaved roads are often treated with dust suppressants, the possible toxic effects of which warrant further study (In prep, Fay and Kociolek). Like the road avoidance zone for birds, a dust avoidance zone was found for ungulate distributions recently (Ndibalema et al. 2007). While chemical constituents are found in tissues of aquatic biota, bioassays suggest highway runoff is not acutely toxic even from high traffic volume roads (Buckler et al. 1999). There is empirical evidence that road salt may be a direct cause of bird mortality, especially in Cardueline finches (e.g., Red Crossbill, White-winged Crossbill, Pine Siskin, Evening Grosbeak), dispelling the notion that it merely serves as an attractant which makes birds vulnerable to vehicle collision (Mineau and Brownlee 2005).

Increased risk of predation and brood parasitism

Success rates of ground nesters are often lower in roaded or linear habitats due to increased edge and nest predation by mammals such as Red Fox (*Vulpes vulpes*) (Greenwood et al. 1995, Frey and Conover 2006). The relationships between the surrounding landscape structure and predator assemblages are complex and not yet fully understood (Bergin et al. 2000, Lariviere 2003, Pescador and Peris 2007). A study using artificial songbird nests with quail eggs found that predators were more likely to use low or medium traffic density roads compared to high traffic corridors, possibly due to the availability of road-killed animals as food sources (Pescador and Peris 2007). As a result, while the noise associated with high traffic volume roads can negatively impact breeding populations of some species, high traffic volume roads appear to pose a lower risk of nest predation (Pescador and Peris 2007). Urban development and roads in forested areas can be associated with increased rates of brood parasitism by Brown-headed Cowbirds (Chace et al. 2003). In the grassland setting, rates of brood parasitism are strongly associated with the presence of trees and shrubs planted along roadcuts (Patten et al. 2006).

4. CONCLUSIONS

4.1. Summary

The construction and maintenance of paved roads and the vehicles which travel upon them pose risks to bird populations. The overarching impact of habitat loss, fragmentation, invasives, and climate change was beyond the scope of this review. While roaded habitats can serve certain ecological functions (Huijser and Clevenger 2006), many bird species avoid roaded habitats for some part of their life cycle (Ferrer and Harte 1997, Parrish et al. 2001, Sara and DiVittorio 2003, Bollinger and Gavin 2004, Arcos and Salvadores 2005, Balbontin 2005, Gorog et al. 2005, Pinto et al. 2005, Carrascal et al. 2006, Gavashelishvili and McGrady 2006). Traffic volume and associated noise appears to be the most important causal factor affecting the densities of breeding bird populations in diverse taxa near roads (Forman et al. 2003, Reijnen and Foppen 2006). For some species, vehicle collisions can have impacts at the population level (Mumme et al. 2000, Reijnen and Foppen 2006, Huijser et al. 2007). While birds do not appear to perceive roads as barriers to movement, their willingness to fly over roads puts them at risk for collision (St. Clair 2003, Gopi Sundar 2004).

It is likely impossible to mitigate every negative consequence along every mile of paved road (Jacobson 2005, Trombulak and Frissell 2000) but a systematic assessment in the form of local scale studies may serve to better understand the extent and magnitude of this pervasive and growing threat to bird populations (Jacobson 2005). This reality is compounded by the challenge of retaining or creating roadless protected areas (Forman and Deblinger 2000, Trombulak and Frissell 2000) and of the extinctions and range shifts that are likely to occur due to climate change (Sekercioglu et al. 2008, National Audubon Society 2009).

4.2. Knowledge gaps

Much remains to be learned about the direct and indirect effects of paved roads to bird populations. This impact is difficult to quantify and requires systematic study of wildlife responses along with species abundance and physical features at local and regional scales (Clevenger et al. 2003, Smith and Dodd 2003, Jacobson 2005, Reijnen and Foppen 2006).

4.2.1. Traffic and associated noise

Riejnen and Foppen (2006) recommended replicating their studies but Kaseloo (2005) suggested using some measure other than bird density (e.g., stress hormones or fledgling success) to better understand the mechanism at play. While the estimated effect distances derived from the work in The Netherlands appear to be reasonable and applicable elsewhere, biases and error probabilities persist and better estimates are needed (Bieringer et al. 2006). It is argued that it is not enough to measure noise alone, but that spatial heterogeneity, diurnal variation of noise levels, and vertical reflective surfaces should also be considered (Warren et al. 2006). In order to increase our understanding of the impact of traffic noise on North American species, more study is warranted.

4.2.2. Roadway lighting

Many rural roads utilize only reflectors for nighttime navigation but some use lighting. Comparisons between lit and unlit roads can be made relative to habitat quality, timing of breeding in roadside territories, vehicle collisions, *et cetera*. Experimenting with colors of roadway lights (van de Laar 2007) may prove relevant to studying contributing factors of road mortality.

4.2.3. Bird–vehicle collisions

Due to the variability in bird road mortality rates from different continents (Errtizoe et al. 2003), deriving an updated North American annual mortality estimate is appropriate. Standardization of studies is necessary in order to account for searcher efficiency and scavenger bias (Erickson et al. 2005). Conducting roadkill surveys in conjunction with species occupancy surveys will help to identify (or estimate) the proportion of species vulnerable to road mortality (Erritzoe et al. 2003, Gopi Sundar 2004, In prep, Longmore et al.). Counting bird carcasses alone may inflate the importance of vehicle collision as a mortality factor for a population, whereas, monitoring marked individuals may provide better insight into the breadth and relative frequency of mortality causes (Aebischer et al. 2005). On the other hand, low bird mortality counts compared to search effort does not necessarily mean that road mortality does not have an effect on vertebrate populations in a particular study area (Clevenger et al. 2003). Rather, the pressure may have already been so great that crossing behaviors may have been selected out of the populations (Clevenger et al. 2003).

Because bird community conservation typically requires large areas, solutions to road-induced problems should consider broad scale road variables (Gutzwiller and Barrow 2003). However, fine scale variables (i.e., road design and immediately adjacent habitat) may prove more useful in predicting collisions than broad scale characteristics (Ramp et al. 2006). It appears that much remains to be learned about population-level impacts of road mortality and which species are affected.

4.2.4. Contaminants

While pollution is considered to have less of a far-reaching effect compared to other highway traffic emissions (Reijnen and Foppen 2006), standardized methods combining analytical chemistry, habitat assessments, and biological assessments are needed in order to determine cause-and-effect relationships between environmental pollution and ecological impairment (Buckler et al. 1999). It is worth pointing out that the ban of leaded gasoline in the 1980–90s has resulted in lower bone lead levels in found road-killed otters, a top predator (Innovations Report 2006). Such studies illustrate the resiliency of the environment when contaminants are identified and appropriate policies are enacted, the valuable uses of road-killed animals, and the correlated benefits to human health.

4.2.5. Increased risk of predation or parasitism

It seems generally accepted that predation rates increase along most roads, but the mechanisms that cause the relationships between the surrounding landscape structure and predator assemblages are complex (Bergin et al. 2000, Lariviere 2003, Pescador and Peris 2007). The work of Pescador and Peris (2007) highlighted the need to better understand the trade offs that may be at play on high traffic volume roads. That is, while high traffic volume may negatively affect breeding productivity via the masking effect of traffic noise, high traffic volume may help reduce vehicle collisions and concomitant predator/scavenger activity.

4.3. Research recommendations for Y2Y ecoregion

Building on previous research conducted by Pearce et al. (2008), the Y2Y ecoregion could serve as a North American case study for paved road effects on birds. For example, the effects of road traffic on breeding bird populations can be studied at the regional scale, following the method of Reijnen and Foppen (2006). At the local scale, avian hotspots identified by Pearce et al. (2008) could serve as study sites. Initiating a baseline and subsequent annual monitoring program at these sites can allow for tracking avian population trends. In addition to classifying by habitat type, roaded sites could be stratified by traffic volume, number of lanes, *et cetera* with non-roaded sites serving as controls. The 109 bird species of concern in the Y2Y region represent diverse taxonomic families and groups (Pearce et al. 2008). In addition to observational studies of birds, experimental mitigation studies in known problem areas may be considered. For any planned road-building or reconstruction projects, pre-construction data should be collected to allow for before–after comparisons (see Ferris 1979). Research priorities may be dictated by Y2Y habitat types or by bird species and guilds. We provide general recommendations based on available risk information associated with the following paved road-related threats.

4.3.1. Population density-depressing effect of traffic

Based on a meta-analysis of 18 different studies representing a variety of habitats and traffic densities, relative risk for a wide range of taxonomic groups can be ascertained (Foppen et al. 2002, Reijnen and Foppen 2006) (Table 1). Data in columns 1–4 are excerpted or interpreted from Figure 2 in Reijnen and Foppen (2006). Column 1 lists taxonomic groups as defined by Reijnen and Foppen. Column 2 lists the number of species they analyzed within each group. Column 3 lists our approximation of the number of species negatively affected within each group. Column 4 lists our approximation of the percentage of species negatively affected within each group. We defined a weighting factor (n/N) as the number of species studied in each taxonomic group divided by the total number of species studied in the meta-analysis. Column 5 lists the weighting factors for each group. Column 6 lists a relative risk as the weighting factor multiplied by the percentage negatively affected within each group. Thus, those groups having a higher relative risk are suggested as priorities for study in the Y2Y.

From the 11 groups analyzed by Reijnen and Foppen (2006), the following five (in descending order) appear to have a higher relative population density-depressing risk from traffic (Table 1):

- Warblers and flycatchers;
- Pigeons, owls, and woodpeckers;
- Thrushes;
- Finches and buntings; and
- Larks, swallows, and pipits.

Table 1. Relative risk to taxonomic groups from negative impacts of traffic (excerpted and adapted from Reijnen and Foppen 2006)

Reijnen and Foppen (2006) taxonomic groups	Number of species analyzed (n)	Approximate number of species negatively affected	Approximate percent significantly negatively affected	Weighting factor (n/N)	Relative risk (weighting factor x percent negatively affected)
waterfowl*	13	2	15%	0.104	1.560
raptors	6	1	15%	0.048	0.720
grouse, rails*	8	2	25%	0.064	1.600
waders, gulls, terns	11	5	45%	0.088	3.960
pigeons, owls, woodpeckers	16	8	50%	0.128	**6.400**
larks, swallows, pipits	9	7	77%	0.072	**5.544**
thrushes	13	8	60%	0.104	**6.240**
warblers, flycatchers	18	8	45%	0.144	**6.480**
tits	11	5	45%	0.088	3.960
crows, starlings*	8	4	50%	0.064	3.200
finches, buntings	12	7	60%	0.096	**5.760**
Totals	125 (N)	57	45%	1	45.424

***Some species in marked groups also showed significant positive impacts from traffic. Bold numbers in final column highlight those groups that may have a higher relative risk based on available information.**

We assigned Y2Y species of concern to Reijnen and Foppen's (2006) taxonomic categories (Appendix B). Most species fit neatly into their classification system. In some cases, more interpretation was required, therefore, assignment considered those bird groups that are often addressed together because of habitat preferences, feeding guilds or other common characteristic. For instance,

- Charadriiformes (e.g., American Avocet, Solitary Sandpiper) and Ciconiiformes (e.g., American Bittern) were grouped with waders, gulls, and terns;
- Gruiformes (e.g., Sandhill Crane) were grouped with grouse and rails;
- Emberizidae (e.g., Brewer's Sparrow), Cardinalidae (e.g., Lazuli Bunting), and Fringilidae (e.g., Red Crossbill) were grouped with finches and buntings;
- Paridae (e.g., Boreal Chickadee) was grouped with tits; and
- Corvidae (e.g., Clark's Nutcracker) was grouped with crows and starlings.

We were not able to assign all species, such as hummingbirds and swifts. More information is needed and/or greater flexibility in category interpretation is required before we can assign the remaining bird species in the context of density-depressing effects from traffic. After assigning all the Y2Y species that could be reasonably assigned within the classification system, the number of species per group was tallied (Figure 1). Species not addressed by Reijnen and Foppen (2006) and, therefore, not assigned, include American Dipper, American White Pelican, Belted Kingfisher, Swifts, Bobolink, Bohemian Waxwing, Brown Creeper, Hummingbirds, Vireos, Common Loon, Shrikes, Red-breasted Nuthatch, Rusty Blackbird, and Western Tanager.

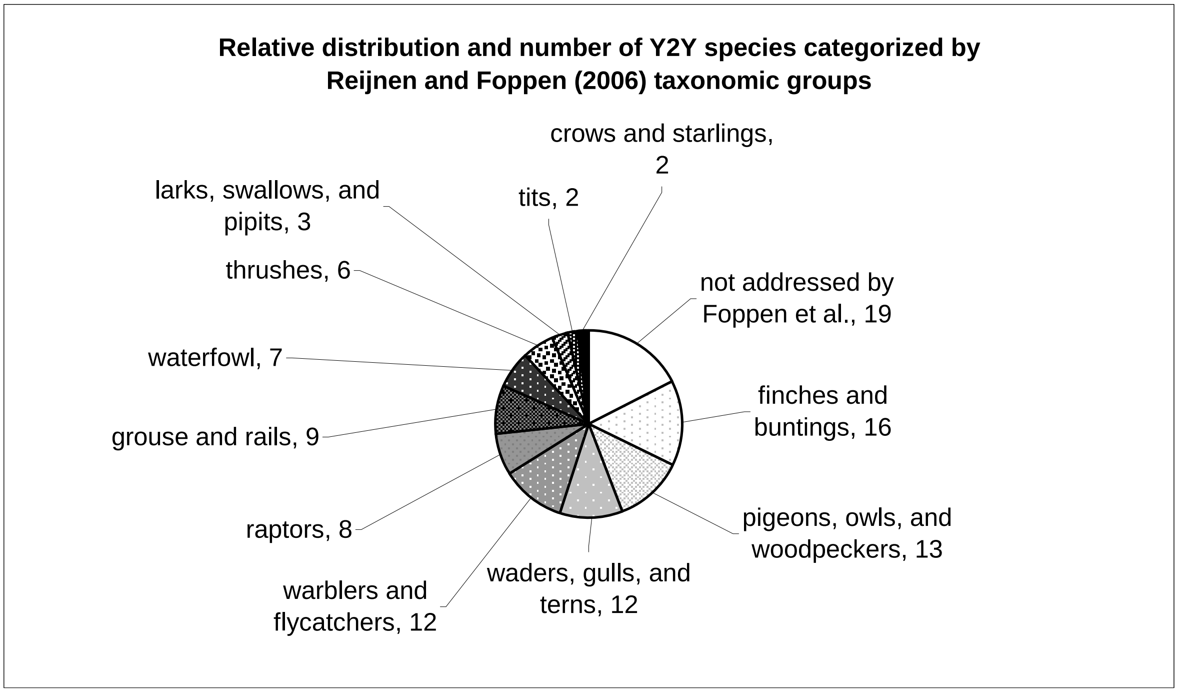

Figure 1. Pie chart of Y2Y's 109 species of concern based on Reijnen and Foppen (2006) taxonomic groups.

Based on the relatively higher numbers of species of concern represented (Figure 1) combined with the weighted relative risk from traffic (Table 1), the following stand out as groups that may be worthy of attention in the Y2Y:

- Finches and buntings (Note: Includes species from Emberizidae, Cardinalidae and Fringilidae. If Lazuli Bunting, the only bunting in Cardinalidae is excluded, the finches and buntings category still remains the largest with 15 species represented.)
- Owls and woodpeckers (Note: Y2Y has no species of concern that are pigeons or doves.)
- Warblers and flycatchers.

Additionally, thrushes and larks, swallows, and pipits also have higher weighted relative risks (Table 1) and may be worthy of attention despite the comparatively low numbers of representative species of concern in these groups. Note that there are no Y2Y species of concern that are larks.

In summary, with regard to studying the density-depressing effect of traffic on Y2Y bird populations, the following three groups (representing 31 species of concern; ~28%) appear to be the most worthy of attention based on higher relative potential risks (Table 1):

- Warblers and flycatchers;
- Owls and woodpeckers; and
- Thrushes.

If the following are also included, these five groups would represent a total of ~50 species of concern (~45%):

- Finches and buntings; and
- Swallows and pipits.

Alternatively, research priorities may be defined by habitat type. Density-depressing effect distances tend to be larger in open versus closed habitats (Reijnen and Foppen 2006). The 19 broad habitat types defined by Pearce et al. (2008) may be classified as open (e.g., grasslands, sagebrush, alpine) or closed (e.g., forested) with the species found in each studied accordingly.

4.3.2. Traffic noise and bird communication

Of the groups that emerged in the previous analysis, owl vocalizations are typically in the lower end of the frequency spectrum, as is traffic noise (Slabberkoorn and Ripmeester 2008). This may make owls relatively more sensitive to the masking effect of traffic noise (Slabberkoorn and Ripmeester 2008). It might be useful to classify all Y2Y birds according to the frequency range of their vocalizations so that comparisons between groups with regard to traffic noise can be made. While birds that communicate in low frequencies appear to be most affected by traffic noise, birds that sing at higher frequencies are also at risk if the amplitude of anthropogenic noise is high enough to mask high-pitched songs (Slabberkoorn and Ripmeester 2008). As a result, it may be difficult to prioritize Y2Y species for study based on song frequency ranges alone.

4.3.3. Effects from roadway lighting

As part of a road infrastructure data set, it might prove useful to also consider roadway lighting. Given the research on roadway lighting in The Netherlands focused on the Black-tailed Godwit, it might be worth focusing on Y2Y's shorebird species of concern (i.e., Long-billed Curlew, Killdeer, sandpipers) or other open habitat birds.

4.3.4. Direct and indirect mortality

Based on the literature, the Barn Owl is the most obvious species in the Y2Y for which direct road mortality might be a major threat at the population level. The Barn Owl is not one of the 109 species of concern in the Y2Y but its distribution currently encompasses part of the southernmost third of the ecoregion (Cornell University 2005). So that meaningful comparisons can be made, any road mortality study on the Barn Owl in the Y2Y should consult and/or replicate the 2007 Idaho study including pesticide analysis as a potential contributor to mortality (Boves 2007). Anecdotal web-based reports of mass road mortality of winter finches in northern regions identify this group as one that may be especially worthy of attention in the Y2Y with regard to vehicle collision and the potential role of deicing salt in bird mortalities (Mineau and Brownlee 2005).

It can be argued that it may be worthwhile determining if road mortality may be contributing substantially to declining population trends for any of Y2Y's 109 species of concern. The existing Breeding Bird Survey (BBS) citizen science effort (http://www.pwrc.usgs.gov/BBS/) offers an opportunity to readily collect roadkill data. BBS surveys are conducted from the road and the same routes are driven each year. While such data would offer only a snapshot in time and would not account for scavenger or searcher bias, they would afford easy broad-based collection over time and space. Such an effort could also provide insight into the relative rates of road mortality by species or habitat type.

For toxicological studies, it might be worthwhile to prioritize Y2Y species of concern that utilize waterways where runoff accumulates (i.e., waterfowl, waders), and higher tropic level and longer-lived birds where bioaccumulation is a concern (i.e., raptors). Regarding indirect effects of roads on bird predation, it may be useful to prioritize songbirds, woodpeckers, and ground nesting birds. Any research exploring potential population level impacts from indirect road-related sources of mortality could allow better understanding of the overall effect of paved roads.

4.4. Conservation action opportunities in the Y2Y ecoregion

In addition to building on previous avian research within the Y2Y, opportunities may exist for increasing the overall awareness of paved road-related threats to birds. The potential benefits of reaching out to each group are listed below:

- General public
    - increased funding for conservation, advocacy and research; decreased road mortality; increased support for mitigation measures and land use planning that considers birds; incentive to utilizing alternative transportation
- Birding community
    - rise in citizen science participation; greater insight into species or habitats most affected
- Students
    - inspire interest and study; develop awareness of the effects of roads and motorized travel
- Resource managers
    - increased interest in and use of mitigations
- Academics
    - increase interest and collaboration on standardizing research; interdisciplinary exchange

More research is needed to quantify effectiveness of mitigation measures, however, certain practices may aid in minimizing the impact of roads and traffic on birds.

- Avoid new road building.
- Avoid unnecessary lighting.
- Explore sound attenuation mitigation options while trying to avoid unintended consequences of posing barriers to other wildlife or increased mortality.
- In areas of known bird road mortality, institute seasonal speed limit reductions.
- On bridges with known bird road mortality, install vertical poles to encourage higher flight.
- Avoid planting attractants such as fruit-bearing shrubs in medians or on roadsides.

5. APPENDIX A – SCIENTIFIC SPECIES NAMES

Common name (alphabetical order)	**Scientific name**
American Avocet	*Recurvirostra americana*
American Bittern	*Botaurus lentiginosus*
American Dipper	*Cinclus mexicanus*
American White Pelican	*Pelecanus erythrorhynchos*
Audubon’s Crested Caracara	*Polyborus plancus audubonii*
Barn Owl	*Tyto alba*
Belted Kingfisher	*Megaceryle alcyon*
Black-tailed Godwit	*Limosa limosa*
Bobolink	*Dolichonyx oryzivorus*
Bohemian Waxwing	*Bombycilla garrulus*
Boreal Chickadee	*Poecile hudsonica*
Brewer’s Sparrow	*Spizella breweri*
Brown Creeper	*Certhia americana*
Brown-headed Cowbird	*Molothrus ater*
Burrowing Owl	*Athene cunicularia*
Clark’s Nutcracker	*Nucifraga columbiana*
Common Loon	*Gavia immer*
Evening Grosbeak	*Coccothraustes vespertinus*
Florida Scrub-Jay	*Aphelocoma coerulescens*
Great Bustard	*Otis tarda*
Hawaiian Goose	*Branta sandvicensis*
Lazuli Bunting	*Passerina amoena*
Long-billed Curlew	*Numenius americanus*
Ovenbird	*Seirus aurocapilla*
Pied Flycatcher	*Ficedula hypoleuca*
Pine Siskin	*Carduelis pinus*
Red Crossbill	*Loxia curvirostra*
Red-breasted Nuthatch	*Sitta canadensis*
Royal Tern	*Thalasseus maximus*
Sandhill Crane	*Grus canadensis*
Solitary Sandpiper	*Tringa solitaria*
Spanish Imperial Eagle	*Aquila adalberti*
Western Tanager	*Piranga ludoviciana*
White-winged Crossbill	*Loxia leucoptera*
Willow Warbler	*Phylloscopus trochilus*

6. APPENDIX B – ASSIGNMENT OF Y2Y SPECIES OF CONCERN INTO REIJNEN AND FOPPEN (2006) GROUPS

Y2Y 109 species of conservation priority	Categorized according to Reijnen and Foppen (2006) groups	Y2Y 109 species of conservation priority	Categorized according to Reijnen and Foppen (2006) groups
Alder Flycatcher	warblers, flycatchers	Mountain Chickadee	tits
American Avocet	waders, gulls, terns	Northern Goshawk	raptors
American Bittern	waders, gulls, terns	Northern Hawk-Owl	pigeons, owls, woodpeckers
American Dipper	not addressed	Northern Pygmy-Owl	pigeons, owls, woodpeckers
American Golden-Plover	waders, gulls, terns	Northern Rough-winged Swallow	larks, swallows, pipits
American Pipit	larks, swallows, pipits	Northern Shrike	not addressed
American Tree Sparrow	finches, buntings	Northern Waterthrush	warblers, flycatchers
American White Pelican	not addressed	Olive-sided Flycatcher	warblers, flycatchers
American Wigeon	waterfowl	Peregrine Falcon	raptors
Bald Eagle	raptors	Pine Grosbeak	finches, buntings
Bank Swallow	larks, swallows, pipits	Plumbeous Vireo	not addressed
Barrow’s Goldeneye	waterfowl	Prairie Falcon	raptors
Belted Kingfisher	not addressed	Red Crossbill	finches, buntings
Black Rosy-Finch	finches, buntings	Red-breasted Nuthatch	not addressed
Black Swift	not addressed	Redhead	waterfowl
Black Tern	waders, gulls, terns	Red-naped sapsucker	pigeons, owls, woodpeckers
Black-backed Woodpecker	pigeons, owls, woodpeckers	Rock Ptarmigan	grouse, rails
Blackpoll Warbler	warblers, flycatchers	Ruffed Grouse	grouse, rails
Blue Grouse	grouse, rails	Rufous Hummingbird	not addressed
Bobolink	not addressed	Rusty Blackbird	not addressed
Bohemian Waxwing	not addressed	Sage Grouse	grouse, rails
Boreal Chickadee	tits	Sandhill Crane	grouse, rails
Boreal Owl	pigeons, owls, woodpeckers	Short-eared owl	pigeons, owls, woodpeckers
Brewer’s sparrow	finches, buntings	Smith’s Longspur	finches, buntings
Brown Creeper	not addressed	Solitary Sandpiper	waders, gulls, terns
Burrowing Owl	pigeons, owls, woodpeckers	Spotted Sandpiper	waders, gulls, terns
Calliope Hummingbird	not addressed	Spruce Grouse	grouse, rails
Cassin’s Finch	finches, buntings	Surfbird	waders, gulls, terns
Cassin’s Vireo	not addressed	Swainson’s Hawk	raptors
Clark’s Nutcracker	crows, starlings	Swainson’s Thrush	thrushes
Columbian Sharp-tailed Grouse	grouse, rails	Three-toed Woodpecker	pigeons, owls, woodpeckers
Common Loon	not addressed	Timberline Sparrow	finches, buntings
Dark-eyed Junco	finches, buntings	Townsend’s Solitaire	thrushes
Dusky Flycatcher	warblers, flycatchers	Townsend’s Warbler	warblers, flycatchers
Ferruginous hawk	raptors	Trumpeter Swan	waterfowl
Flammulated Owl	pigeons, owls, woodpeckers	Tundra Swan	waterfowl
Forster’s Tern	waders, gulls, terns	Varied Thrush	thrushes
Golden Eagle	raptors	Vaux’s swift	not addressed
Golden-crowned Sparrow	finches, buntings	Veery	thrushes
Grasshopper Sparrow	finches, buntings	Warbling Vireo	not addressed
Gray Jay	crows, starlings	Western Screech Owl	pigeons, owls, woodpeckers
Gray-cheeked Thrush	thrushes	Western Tanager	not addressed
Gray-crowned Rosy Finch	finches, buntings	Western Wood-Pewee	warblers, flycatchers
Green-tailed Towhee	finches, buntings	White-crowned sparrow	finches, buntings
Gyrfalcon	raptors	White-headed Woodpecker	pigeons, owls, woodpeckers
Hammond’s Flycatcher	warblers, flycatchers	White-tailed Ptarmigan	grouse, rails
Harlequin duck	waterfowl	White-winged crossbill	finches, buntings
Killdeer	waders, gulls, terns	Williamson’s Sapsucker	pigeons, owls, woodpeckers
Lazuli Bunting	finches, buntings	Willow Flycatcher	warblers, flycatchers
Lesser yellowlegs	waders, gulls, terns	Willow Ptarmigan	grouse, rails
Lewis’ Woodpecker	pigeons, owls, woodpeckers	Wilson’s Phalarope	waders, gulls, terns
Loggerhead Shrike	not addressed	Wilson’s Warbler	warblers, flycatchers
Long-billed Curlew	waders, gulls, terns	Wood Duck	waterfowl
MacGillivray’s Warbler	warblers, flycatchers	Yellow Warbler	warblers, flycatchers
Mountain Bluebird	thrushes		

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