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Can roads, railways and related structures have positive effects on birds? – A review

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ABSTRACT

The urbanization process affects faunal distributions and movement patterns, contributing directly to biotic homogenization and representing an important threat to biodiversity. In particular, birds, which have been well studied as indicators of anthropogenic disturbance, are especially valuable in evaluating these impacts.

While the negative impact of these processes and structures, most notably road and railway networks, are now well appreciated (e.g. habitat loss, disturbance, noise, mortality by collisions, barrier effects), the potentially positive effects on wildlife are less appreciated (the number of documented negative effects of roads on animal abundance outnumbered the number of positive effects by a factor of 5). Here, were reviewed a total of 92 peer-reviewed publications for the period of 36 years between 1978 and 2014, which reported positive effects of roads and associated anthropogenic structures on birds. Our results show that roads, railways and several associated constructions, commonly implicated in the decline of biodiversity, may also have positive effects on certain bird species or communities. The main types of positive effects on birds identified were classified as: (1) roads: providing foraging habitat; reducing the predation pressures; and providing a warm surface assists in conserving metabolic energy; (2) lights of streets: prolonging diurnal activity; (3) powerlines, fences, etc. along roads: providing perches for hunting activities; and (4) bridges, pylons, tree lines along roadsides, bases of powerline pylons: providing nesting sites and cover from predators. From this review, we provide a useful tool for ecologists, road planners and other stakeholders engaged on conservation or landscape planning.

Introduction

Urbanization can be characterized by the concentration of human presence in residential and industrial settings, with road or railway networks developed to connect these centers being a major component (Marzluff, 1997). These features have come to constitute one of the major causes of landscape change, and representing an important threat to biodiversity (Sala et al., 2000; Sanderson et al., 2002; Wilcox and Murphy, 1985). The process and geography of urbanization directly affect faunal distribution and movement patterns and contributes directly to biotic homogenization (Blair, 1996; Clergeau et al., 1998, 2001, 2006; Devictor et al., 2007; Faeth et al., 2011; Li et al., 2010; McKinney, 2006). Moreover, during the past

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century, many of the structures associated with linear infrastructure such as roads, railways, electricity power easements, fences, etc. have become a conspicuous part of the anthropogenic landscape (Grimm et al., 2008; Tryjanowski et al., 2013). The negative impact of these features, most notably of road and railway networks, on all landscapes are now well appreciated (Bennett, 1991; Forman et al., 2003; Kociolek et al., 2011). With transportation corridors continuing to expand globally, we ask whether the prospects for biodiversity all bad?

Road and railways in numbers

According to the data of World Development Index of World Bank, World Road Statistics of the International Road Federation and of World Factbook of the Central Intelligence Agency on the World there are currently circa 35,500,000 km of all roads globally. The network of paved roads is estimated on 14,600,000–15,200,000 km while motorways and expressways together are about 375 000 km. On the other hand, according to the International Union of Railways (UIC) at November 1st 2013 there was 1,370,000 km of railway worldwide of which 21,472 km (1.6%) comprises high speed railways (Vmax> = 250 km/h). The two largest high speed rail networks are in the People's Republic of China with 9867 km and Spain with 2515 km (UIC, 2013). Although some countries are reducing the expansion of high speed railways (e.g. the motherland of TGV, France, after political changes in 2012, would like to move the emphasis on the improvement of conventional railways, while in 2011 Poland cancelled a project of 450 km network), 13,964 km of high speed track remains under construction (UIC, 2013). The most ambitious investments are the present leaders: China (9081 km) and Spain (1308 km), while confirmed plans globally are for 16,347 km (UIC, 2013). By 2025 there should be 51,784 km of high speed network worldwide.

Main effects of roads and railways on wildlife

Roads and railways are pervasive features of the landscape and their ecological effects on vertebrate wildlife have been well documented (Van der Zande et al., 1980; Bennett, 1991; Forman, 1995; Forman and Alexander, 1998; Spellerberg, 1998; Forman and Deblinger, 2000; Trombulak and Frissell, 2000). The primary categories of ecological effects on wildlife may be summarized as follows:

- *Habitat loss:* the construction of roads and railroads always implies a net loss of wildlife habitat. The physical encroachment on the land gives rise to disturbance and barrier effects that contribute to the overall habitat fragmentation due to infrastructure (Kociolek et al., 2011).
- *Disturbance:* roads, railroads and traffic disturb and pollute the physical, chemical and biological environment and consequently alter habitat suitability for many plant and animal species for a much wider zone than the width of the road or railroad itself (Forman and Alexander, 1998). Furthermore, indirect effects may exert a significant influence. These effects include noise (Kaseloo and Tyson, 2004) and artificial light. The latter, for example, can influence avian biorhythms with regard to development, singing patterns, breeding, molting, migration (De Molenaar et al., 2006).
- *Mortality:* collisions with traffic causes the death of many animals that utilize verge habitats or try to cross the road or railroad. Traffic mortality has been growing constantly over the years, but is considered as a severe threat in only a few species (Reijnen and Foppen, 2006).
- *Barrier:* for most non-flying terrestrial animals, infrastructure implies movement barriers that restrict the animals' range, make habitats inaccessible and can potentially lead to fragmentation and isolation of populations (Van der Ree et al., 2007).

The effects described above have mainly negative effects on vertebrates (Gonzalez-Gallina et al., 2013; Kociolek et al., 2011; Palomino and Carrascal, 2007). In fact, overall, the number of documented negative effects of roads on animal abundance outnumbered the number of positive effects by a factor of 5 (Fahrig and Rytwinski, 2009).

The human-dominated landscape presents particular challenges to researchers because the effects of urbanization on ecological processes are often complex and not well understood (Gering and Blair, 1999). To address these issues, the fields of urban ecology and road ecology have been attempting to take into account the main effects of urban developments and transportation networks on animal and plant distribution and movements (Beissinger and Osborne, 1982; Davis and Glick, 1978; Gilbert, 1989; Niemelä, 1999). In particular, birds have been studied as indicators of disturbance associated with anthropogenic structures on wildlife (Marzluff et al., 2001), because compared to other vertebrates, birds are easily monitored by skilled observers and provide a mechanism to explore urban effects and responses to different urban designs (Chace and Walsh, 2006).

As the global human population continues to increase, the expansion of urban areas and associated road networks is inevitable. Moreover, the associated ecological footprint, already too large, continues to expand (Bissonett, 2002). For this reason, appropriate knowledge and understanding of the relationships among bird species and roads, railways and associated structures should be useful for conservation-focused landscape planning.

Currently, modern techniques increasingly used in modelistic approaches (SDMs, niche models, etc.) (Geange et al., 2011; Guisan and Zimmermann, 2000; Guisan et al., 2007), and the possibility of studying (by mean of hierarchical procedures) the relative importance of predictors or environmental variables (Morelli, 2013a) on species occurrences, provides an opportunity to contribute to understanding the effect of individual components of anthropogenic landscapes on bird communities.

Many of the negative effects of roads, railways and associated structures along roadsides on wildlife are associated with direct mortality, habitat fragmentation, audiovisual disturbance and chemical pollution (Bevanger, 1998; Forman et al., 2003; Janss, 2000; Infante and Peris, 2003; Kociolek et al., 2011; Li et al., 2010; Orłowski, 2008; van der Ree et al., 2011), but also influence avian population quality (Bujoczek et al., 2011). The possibility that there may be positive effects of roads and associated human structures is rarely mentioned in the literature. Therefore, a comprehensive survey of negative and positive effects of road-related structures on bird species should help develop a suitable approach to assisting understand the overall effect of roads on bird communities.

In this paper, we collected and classified the available information about the main positive effects of roads and associated human structures on birds, the bird species or group of species involved, and the corresponding references. As result, we provide a useful record for ecologists, road planners and other stakeholders engaged in on conservation or landscape planning considerations.

Methods

We conducted a literature search through the main web search engines, including Google Web and Scholar, as well as relevant ecological and avian journals directly. We searched for terms: bird(s), raptor(s), avian, and avifauna with any of the following additional terms: road, roadside, highway, trail, motorway, railway, train, bridge, pin, barbed wire, powerlines, pylons, traffic, collision, roadkill, human-related structures, signboards, windbreaks (linear strips of planted trees or retained remnant vegetation to protect commercial crops or roads from wind-damage), artificial lights, etc.

As a result, we reviewed a total of 92 publications for the period of 36 years between 1978 and 2014, published on peer reviewed journals, and two articles in press. However, the vast majority of articles consulted were published after 2000. We screened each publication for terms used to define the positive effects of roads, railways and related human structures on birds, the bird species or group target of these effects, and the explanation suggested by authors of these studies.

The main categories of road, railways and associated structures considered in this work were classified as following: highways, roads (paved, unpaved roads and trails), railways, bridges, artificial light along roads, electricity powerlines, barbed wires, signboards, windbreaks and other structures related to transport network (Figs. 1 and 2).

Results

Records on positive effects of roads, railways and related structures on bird species and communities were found in published accounts from throughout the world. For illustration on the positive effects of these structures on bird species, we selected several examples from major regions (North America, South America, Europe, South Africa, Western Asia, East Asia, South Asia and Oceania). The positive effects, target species and the corresponding references are showed in the Table 1. A

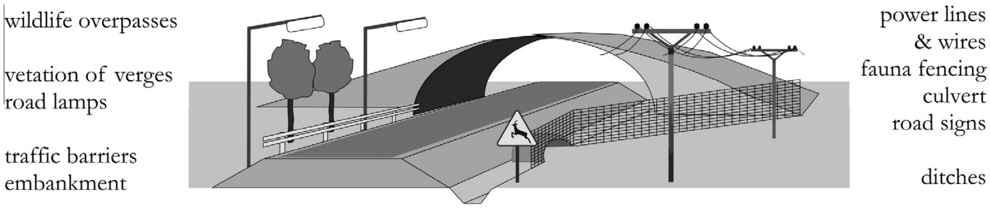

Fig. 1. Schematic representation of road and the main associated human structures that can provide positive effects on birds.

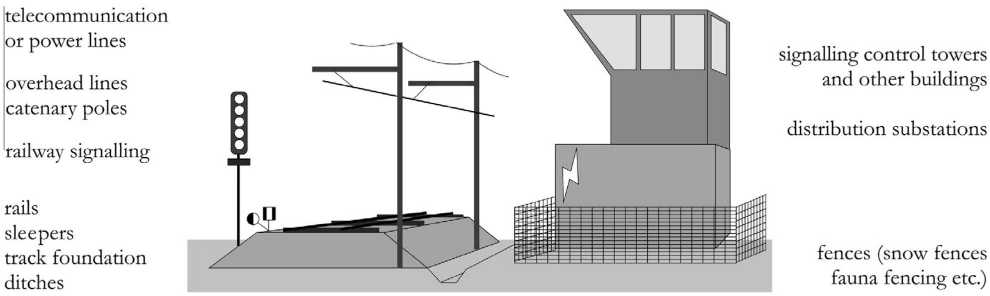

Fig. 2. Schematic representation railway and the main associated human structures that can provide positive effects on birds.

Table 1
Summary of positive effects of roads and associated human structures (bridges, artificial light, marginal vegetation, powerlines, windbreaks) on bird species.

Human-related structure	Bird species/group	Location	Main causes of positive effect reported on references	Reference
Roads	Eurasian Magpie *Pica pica*	Western Asia	Food supply and minor predation pressures	Yamac and Kirazli (2012)
	Lesser kestrel, *Falco naumanni*	Western Asia	Foraging habitat in direct proximity to the main roads	Kmetova et al. (2012)
	Raptors and corvids	South Africa	Roads offer foraging substrate where find preys associated with road-kills	Dean and Milton (2003)
	Skylark, *Alauda arvensis*	Europe	Road sides offer a good foraging habitat and verges constitute suitable nesting sites	Laursen (1981)
	Forest birds, e.g.:	North Europe	Road sides increase landscape heterogeneity, that provide greater available of habitat	Helldin and Seiler (2003)
	Willow warbler, *Phylloscopus trochilus* Great tit, *Parus major* European Greenfinch, *Carduelis chloris* Yellowhammer, *Emberiza. citrinella*			
	Passerines species, e.g.: Corn Bunting, *Miliaria calandra* House Sparrow, *Passer domesticus* Rock Sparrow, *Passer petronia*	Europe	Not specified	Peris and Pescador (2004)
	Forest birds, e.g.:	Europe	Edge effects near to roads can offer major availability of any relevant resource, than far from roads	Palomino and Carrascal (2007)
	Short-toed Treecreeper, *Certhia brachydactyla* European robin, *Erithacus rubecula* Common Chaffinch, *Fringilla coelebs* Coal tit, *Parus ater* Great tit, *Parus major* Blackcap, *Sylvia atricapilla*			
	Red-backed shrike, *Lanius collurio*	Europe	Open space useful as potential foraging substrate	Morelli (2013b)
	Common Whitethroat, *Sylvia communis*	Europe	Open space potential as foraging substrate, thermophile habitat and road verges used as ecological network	Tryjanowski et al. (unpublished data)
	European Greenfinch, *Carduelis chloris* Woodlark, *Lullula arborea* Great tit, *Parus major* Yellow wagtail, *Motacilla flava*			
	Forest birds (few species)	North America	Not specified, but effects were recorded on low-traffic roads	Ferris (1979)
	Passerines species, e.g.:	North America	Road surface functioning as warm microenvironment that help birds to conserve metabolic energy	Whitford (1985)
	Vesper Sparrow, *Pooecetes gramineus* American Robin, *Turdus migratorius* House Sparrows, *Passer domesticus* Mourning Dove, *Zenaida macroura*			
	Turkey Vulture, *Cathartes aura* Black Vulture, *Coragyps atratus*	North America	Road surface provides feeding habitat	Coleman and Fraser (1989)
	Common raven, *Corvus corax*	North America	Road surface and roadside provide availability of dead animals	Knight and Kawashima (1993)
	Florida Scrub-Jay, *Aphelocoma coerulescens*	North America	Road surface and roadside habitat have a positive effect on food availability and energy intake	Morgan et al. (2010)
	Desert tortoise, *Gopherus agassizii*	North America	Low traffic road increase water and forage availability, increasing growth rates and survival	Nafus et al. (2013)
	Eared Doves, *Zenaida auriculata*	South America	Greater proportion of trees near to buildings along roads offer more food and nesting places due to a higher habitat complexity	Leveau and Leveau (2005)
	House Sparrows, *Passer domesticus*			
	Diurnal scavenging raptors, e.g.:	South America	Road surface and roadside provide availability of dead animals, more detectable that far from roads	Lambertucci et al. (2009)

Table 1 (*continued*)

Human-related structure	Bird species/group	Location	Main causes of positive effect reported on references	Reference
	Southern caracaras, *Caracara plancus*			
	Chimango caracaras, *Milvago chimango*			
	Black vultures, *Coragyps atratus*			
	Yellow Thornbill, *Acanthiza nana*	Oceania	Not specified	Fahrig and Rytwinski (2009) based on Pocock and Lawrence (2005)
	Superb Fairy-Wren, *Malurus cyaneus*	Oceania	Not specified	Fahrig and Rytwinski (2009) based on Pocock and Lawrence (2005)
	Black kites, *Milvus migrans*	Oceania	Road surface provide availability of dead animals	Beckmann and Shine (2011)
	Whistling kites, *Haliastur sphenurus*			
Highways	Ground-dwelling birds, e.g.:	East Asia	Road offer nesting sites and foraging opportunities on the verges	Li et al. (2010)
	Rufous-necked snowfinch, *Montifringilla ruficollis*			
	Ground Jay, *Podoces biddulphi*	East Asia	Proximity to highway surface provide good food resource	Xu et al. (2013)
	Levant Sparrowhawk, *Accipiter brevipes*	Western Asia	Use the heat released by the highway surface to improve flight conditions and maximizes timing of migration	Yosef (2009)
Railways	Ground-dwelling birds, e.g.:	East Asia	Railway offer nesting sites and foraging opportunities on the verges	Li et al. (2010)
	Rufous-necked snowfinch, *Montifringilla ruficollis*			
Bridges	Raptor bird species	World	Several human-related structures, as bridges, offer alternative nesting structures	Bird et al. (1996)
	Peregrine Falcon, *Falco peregrinus*	North America	Bridges offer alternative nesting structures	Bell et al. (1996), Temple (1988)
Artificial light along roads	Passerine species, e.g.:	North Europe	Use artificial light to increase their daily activity periods	Byrkjedal et al. (2012)
	European Robin *Erithacus rubecula*			
	Rainbow Lorikeet *Trichoglossus haematodus*	Oceania		Daoud-Opit and Jones (in press)
Marginal vegetation	Farmland birds, e.g.:	Europe	Marginal habitats along roadsides offer perch structures, feeding habitat and nesting structures	Morelli (2013a), Ceresa et al. (2012)
	Red-backed shrike, *Lanius collurio*			
	Cirl bunting, *Emberiza cirlus*			
	European Turtle-dove, *Streptopelia turtur*			
	European goldfinch, *Carduelis carduelis*			
Powerlines	Lesser kestrel, *Falco naumanni*	Western Asia	Electricity cables used for perching, during hunting activities	Kmetova et al. (2012)
	Osprey, *Pandion haliaetus*	Europe	Electricity poles are used as nesting structures	Meyburg et al. (1996)
	Raptor bird species, e.g.:	Europe	Perching sites close to roads (e.g., power lines and telephone poles) as well as prey availability (road kills) may increase the attractiveness of roadsides to raptors. These perching sites, allow a less energy-demanding hunting behavior than flight-hunting	Meunier et al. (2000)
	Buzzard, *Buteo buteo*			
	Kestrel, *Falco tinnunculus*			
	Black kites, *Milvus migrans*			
	Tree Sparrow, *Passer montanus*	Europe	Electricity poles are used as nesting structures	Vepsäläinen et al. (2005)
	Farmland birds, e.g.:	Europe	Electricity poles are used as nesting structures, song posts, or for perching. Marginal habitats around the base of pylons constitute foraging habitat	Tryjanowski et al. (2013)

(*continued on next page*)

Table 1 (*continued*)

Human-related structure	Bird species/group	Location	Main causes of positive effect reported on references	Reference
	Red-backed shrike, *Lanius collurio* Common Whitethroat, *Sylvia communis* Yellowhammer, *Emberiza. citrinella* Corn bunting, *Milaria calandra*			
	Farmland birds (mainly insectivorous species)	Europe	Powerlines used as perch, during hunting activities	Morelli (2013c)
	Cowbirds, *Molothrus* genus	North America	Mowed grass beneath powerlines offer good forage places	Rich et al. (1994)
	Cowbirds, *Molothrus* genus	North America	Powerlines used as perch, to watch for nests to parasitize	Evans and Gates (1997), Gates and Evans (1998)
	Passerine species, shrubland-nesting	North America	Powerline right-of-ways provide refuges of shrub habitat	King et al. (2009)
	Red-tailed hawk, *Buteo jamaicensis*	North America	Powerlines offer good perches to hunt for mammalian prey	DeGregorio et al. (2014)
Windbreaks	Nectarivorous species	South Asia	Windbreaks used as traveling routes, foraging and nesting sites.	Sreekar et al. (2013)

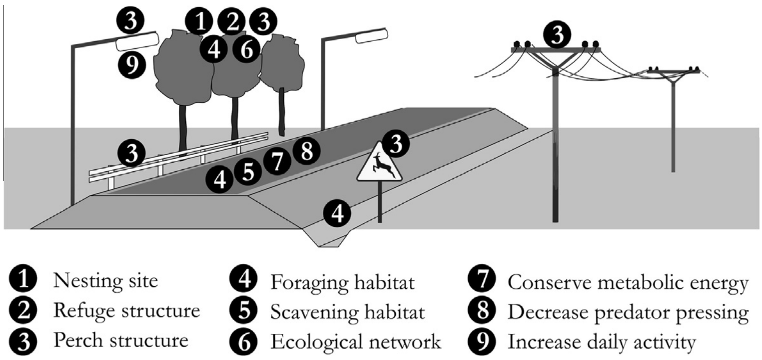

Fig. 3. Schematic representation of the principal positive effects that road, railway and associated human structures can provide on birds.

schematic representation of the main positive effects provided by roads and human associated structures on birds is shown in the Fig. 3.

Discussion

Our results found that roads, railways and several associated structures, commonly related to the decline of biodiversity, may also have positive effects on certain bird species or may influence bird diversity. In many citations, bird communities richness was greater in suburban and periurban areas dominated by road networks compared to rural areas (Leveau and Leveau, 2005), indicating that several of these characteristic features of urban landscapes are attractive to numerous bird species.

For example, females of some species were found in better condition and were reproductively more successful in suburban environments than in agricultural habitats (Cardilini et al., 2013). In fact, when animals are attracted to roads in order to access a resource, provided that they have the cognitive and physical ability to avoid the risk represented by vehicles, there can be a net positive effect of roads on animal abundance (Fahrig and Rytwinski, 2009).

Following Rytwinski and Fahrig (2013), we offer several possible generalized explanations for these positive effects of roads on wildlife populations. First, species that have small territory sizes and high reproductive rates (such as small mammal species) are not likely effect by road mortality at the population level (Rytwinski and Fahrig, 2013). Second, species that use road or associated structures may be unaffected by roads provided they are able to avoid collisions with vehicles (Jaeger et al., 2005). And finally, roads may indirectly produce a net increase in abundance of species whose predators show negative population-level responses to roads, through predation release (Rytwinski and Fahrig, 2013).

Other indirect benefits on birds provided by linear infrastructures related to aerial transportation such as airport runways or other structures, were recorded in literature. For example, stormwater impoundments are often used as water resources for several bird species (Fox et al., 2013), while the presence of airfield grasslands and solar photovoltaic installations at airports can be correlated with increased bird abundance (DeVault et al., 2014).

From the examples considered in this review, we can add some new potentially positive effects of roads and railways on bird populations, related mainly to the provision of alternative feeding habitat or nesting sites, as well as elements that increase landscape heterogeneity and which enhance foraging opportunities of some bird species or improve their metabolic rate (references on the Table 1). The main positive effects and each related human structures on birds were classified as follows:

- *Roads, highways, etc.:* providing foraging habitat due to an increase of food availability, reducing the predation pressures due to a minor presence of natural predators, and providing a warm surface assists in conserving metabolic energy.
- *Roadside vegetation and open spaces:* providing foraging habitat due to an increase of food availability, providing habitats useful as ecological corridors.
- *Artificial lights along roads:* providing foraging habitat due to an increase of food availability, also in time, to prolong their diurnal activity during winter.
- *Powerlines, barbed wires, pins, signboards, and other common human structures associated to roadside:* providing perches for hunting activities (mainly for insectivorous species or raptors), providing song-post.
- *Bridges, pylons and tree lines along roadside:* providing nesting sites and reducing predation pressures.
- *Bases of powerlines pylons, windbreaks, flower beds, etc.:* providing foraging habitat due to an increase of food availability, providing nesting sites, increasing habitat quality by the effect of landscape heterogenization, providing good hiding to avoid predators, and providing marginal habitats, useful as ecological corridors.

The bird species positively affected by road presence were numerous. Here we can attempt a brief classification of general avian categories: (1) raptors, scavenging raptors and shrikes that use road surfaces as hunting substrate (capturing preys or taking advantage of roadkill); (2) farmland birds that are favored by structures associated to roads as pylons, powerlines, fences and signboards, useful as perches and song-posts; (3) raptors, corvids and other bird species that use bridges and other structures associated to roads as nesting sites, often conferring a greater reproductive advantage than wild sites (Chace and Walsh, 2006); (4) passerine species that use the warm surface of roads to conserve metabolic energy; (5) passerine species that exploit artificial light along roads to increase their daily activity period; and (6) many bird species typical of woodlands that are attracted to roadsides due to edge effects, if the availability of any relevant resource is higher in the road margins than in sites away from these habitat borders (Palomino and Carrascal, 2007).

It is important to emphasize, however, that the positive effects of roads on birds reported in the literature were mainly associated with unpaved roads or paved roads with low traffic flow. The intensification of traffic is likely to cause an increase in mortality by direct collision (Erritzoe et al., 2003), which may reduce or cancel the positive effects above described (Reijnen and Foppen, 2006).

The results of this review also highlight the importance of roadside vegetation (verges, hedgerows) as ecological corridors for many invertebrates (Vermeulen and Opdam, 1995; Vermeulen, 1994), transforming these particular marginal habitats into suitable foraging habitat for many insectivorous bird species (Morelli, 2013a). Similarly, the low vegetation around the base of pylons, often along roadsides, seems to operate in a similar way (Tryjanowski et al., 2013).

Furthermore, other anthropogenic structures typical of roads and roadsides, such as wire fences, powerlines and signboards, may be attractive to bird species because they offer greater environmental heterogeneity. This effect may be most marked in generalist and opportunist birds able to take an advantage of the new habitat offered by humans (Lambertucci et al., 2009). Nevertheless, the effects of roads and railways as a source of environmental heterogeneity should be strongest on homogeneous landscapes such as intensive farmlands, forest or extended grasslands. Fernandez-Juricic (2000, 2001) noted that wooded streets could potentially function as corridors, offering to certain species (particularly those feeding on the ground and breeding in trees or tree holes) alternative habitat for feeding and nesting. In the same way, the characteristics offered by railways could constitute positive variables for several bird species. Some examples of potential positive effects of railways and associated human structures on birds are summarized in the Table 2.

Table 2
Summary of potential positive effects of railways and associated human structures on bird species.

Human-related structure	Bird species/group	Main causes of positive effect reported on references
Railways	Passerine species	Marginal habitats along railways offer nesting structures (shrubs, bridges, etc.)
	Passerine species	High constructions along the tracks (poles, wires) are used to singing, displaying, resting and perching
	Passerine species (mainly granivorous)	Railway embankments provide a good source for gastroliths, useful for digestive purposes by several bird species, that ingest these small stones that help in the stomach to grind ingested food material
	Passerines species	Railways surface provide a good source of sand, used by several bird species to make the sand-bathing, useful to clean the feathers
	Passerine species	Tracks serve as a resting place (it heats up quickly in summer, it is protected from snow and wind in winter)
	Passerine and other scavenger species	Railway surface provide good foraging places

Numerous urban ecology studies underline the importance of identifying the different urban structures which support habitat for several animal species, and exploring the different responses for different species (Jarošík et al., 2011). In fact, the same bird species can display differing responses to urbanization (Møller et al., 2012; Tryjanowski et al., 2013). For this reason, a more accurate assessment of road and rail network and associated structures effects on bird species (taking into account both negative and positive effects), may be helpful in improving policies associated with the conservation of biodiversity, landscape restoration and urban planning, assisting the implementation of suitable measures to assist in addressing biodiversity decline in human-dominated environments.

Our results are evidence that even anthropogenic structures can be used successfully to increase the biodiversity in urban environments, and also to schedule species conservation strategies. Associated structures such as bridges and tunnels may also provide habitats for some taxa (Spellerberg, 1998). And it is clear that a reduction in both direct and indirect effects of roads and road networks must be the goal of management agencies (Benitez-Lopez et al., 2010; Bissonett, 2002). However, more detailed and focused research is needed; too many critical gaps in knowledge remain. For example, a simulation study (Rytwinski and Fahrig, 2013) found that in rural landscapes containing high-traffic roads, many bird species appeared to be advantaged due to a reduced predation by generalist road-affected predators. Rytwinski and Fahrig (2013) state that: "the simulations do not support the idea that a species, either large or small, that is attracted to the road for a resource and able to avoid oncoming vehicles should show a positive population-level response to roads; rather, the simulations predict a neutral effect in these cases". This particular result, suggests that the apparent positive effects of road attraction on raptors abundance may be not real in some cases.

An additional issue, highlighted by Jaeger et al. (2005), is the importance of each species' capacity to reduce the negative effects of roads and the "road avoidance behavior" of individuals of the species that can enable the use of road, roadside and associated human structures as alternative habitat. Furthermore, the type of road or railway must be accurately specified, because several types can cause different effects on bird communities. Research on the type of road and railway must distinguish speed traffic, purpose, location, surface or separation (see Appendix A).

In conclusion, we suggest that any attempt to describe the overall effects of road network on birds, must be take into account both negative (more numerous, more studied) and positive effects on bird populations. In the same way, the few positive effects of roads and associated human structures on birds must be considered only as a balance between the potential positive effects mentioned in the text and the road-kill risk, always present and subordinated to the traffic-flow.

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Appendix A

Classification of the main type of roads, railways and human structures associated.

Types of roads

1. By purpose.
   a. singe carriageways roads:
      a. one or two-lane roads,
      ii. multiline roads (2 + 1, 2 + 2)
      iii. service roads/frontage roads/local roads besides freeways
   b. double carriageways roads:
      i. roads with central reservation (median)
      ii. expressways (called as freeways)
      iii. highways (freeways)

2. By location.
   a. in urban areas (with sidewalks, cycleway, parking places, greenery, etc.)
   b. outside urban areas (with e.g. hard shoulder, verge, ditches)
3. By surface.
   a. ground roads
   b. gravel roads
   c. paved with stones
   d. paved with concrete pavers or bricks,
   e. chipseal road

   f. asphalt concrete
   g. concrete
4. By separation.
   a. on the level of ground
   b. separated by ditches etc.
   c. grade separated
   d. artificial separation (noise barriers, roadside fencing)
   e. some other road constructions and objects:
   f. culverts
   g. bridges
   h. tunnels
   i. wildlife crossings
   j. road signs (traffic lights) constructions
   k. toll collection areas
   l. park places
   m. filling and service stations

Types of railways tracks

1. Division by speed.
   a. conventional diesel lines (usually up to 120 km/h)
   b. conventional electrified lines (up to 160 km/h)
   c. fast lines (161–249 km/h)
   d. high speed lines (250 km/h and more)
   e. special constructions of lines (e.g. rack railways)

Speed causes: more space between tracks, more complicated train control systems, density of masts of overhead lines, fences against animals, noise barriers, higher density of electricity distribution stations.

1. Division by number of tracks.
   a. single track
   b. double track
   c. multiple track (on main corridors, e.g. *Rhine Valley Line*)
2. Division by construction of sleepers: (sleeper = railroad tie; both forms of name in use).
   a. wooden sleepers (old type solution often on branch lines; nowadays used only in places where the reduction of vibration is needed, e.g. on some bridges)
   b. concrete sleepers (the most common solution)
   c. steel sleepers (very seldom)
   d. concrete slab track (usually on some parts of high speed lines, popular in German)
3. Division by construction of track bed (the groundwork onto which a railway track is laid).
   a. ballast tracks
   b. ballast less tracks (there are lab track needed)

Permanent way in railways means: rails, sleepers and track bed. Below you have usually the track formation (the prism of stones smaller than ballast and soils) – blanket and subgrades. Besides you have usually ditches.

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