Chapter 1
Railway Ecology

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Abstract Railways play a major role in the global transportation system. Furthermore, railways are presently being promoted by several governments thanks to their economic and environmental advantages relative to other means of transportation. Although railways have clear advantages, they are not free of environmental problems. The objective of this book is to review, assess, and provide solutions to the impacts of railways on wildlife. We have divided the impacts of railways on biodiversity into four main topics: mortality, barrier effects, species invasions, and environmental disturbances, with the latter ranging from noise to chemical pollution. Railways share several characteristics with roads and with power lines when the trains are electric. Therefore, much can be learned from studies on the impacts of roads and power lines, taking into account, however, that in railways, the two are often combined. Besides the similarities with roads and power lines, railways have specific characteristics. For instance, railways have lower traffic intensity but trains usually have much higher speeds than road vehicles, and the electric structures in railways are typically lower than in most power lines. Thus, railways pose specific challenges and require specific mitigation measures, justifying calling the study of its impacts on biodiversity "railway ecology."

Keywords Barrier effects · Disturbances · Invasions · Linear infrastructures · Mortality · Railway ecology

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Introduction

The most basic definition of a railway is “a prepared track which so guides the vehicles running on it that they cannot leave the track” (Lewis 2001). According to this definition, railways were already used by the Greeks and Romans. However, the concept of railway as we know it today—that is, rails made of iron, with trains composed of several wagons pulled by one or more locomotives running on specified timetables, forming nationwide or international networks—is an invention of the early nineteenth century (Lewis 2001).

Since its inception, the technology of rails and trains has evolved considerably. Two main forces have driven this evolution: the reduction of costs and the increase in safety (Shabana et al. 2008; Flammini 2012; Profillidis 2014). The reduction of costs has been achieved by increasing energy efficiency and, simultaneously, increasing the speed and size of the trains. According to the International Energy Agency and the International Union of Railways, from 1975 until 2012, the energy used by passenger/km decreased by 62%, while the energy to transport cargo by tonne-km decreased by 46% (Railway Handbook 2015). This increase in energy efficiency was accompanied by a 60% reduction in CO_2 emissions for passenger and 41% for freight transportation (Railway Handbook 2015). Three countries—China, India, and Russia, with extensive railway networks, and where associated environmental impacts are likely to be important—exemplify these achievements. China boasts 60% (27,000 km) of the total high-speed lines in the world and has the lowest rate of energy consumption per passenger-km (67 kJ/passenger-km). India has the lowest CO_2 emissions per passenger-km (10 g CO_2/passenger-km) and the lowest rate of energy consumption per tonne of goods transported (102 kJ/tonne-km). Russia has the lowest CO_2 emissions per tonne of goods transported (9 g CO_2/tonne-km) (Railway Handbook 2015).

Increases in railway safety have also been substantial, not only for passengers, railway workers and freight, but also for the human populations living in the vicinity of the railways (Shabana et al. 2008; Flammini 2012; Profillidis 2014). The safety achieved in the railway sector is particularly impressive when compared to road safety. According to a report by the European Railway Agency (2013), the fatality risk in the period 2008–2010 measured as the number of fatalities per billion passenger-km is 0.156 to railway passengers and 4.450 for car occupants. In fact, following the same report, transport safety is only surpassed by the airline industry with 0.101 fatalities per billion passenger-km.

Besides economic and safety advantages, there is general agreement that railways have several environmental advantages relative to roads. We highlight two of them: Firstly, railways are less pollutant than roads because the metal-to-metal contact characteristic of railways considerably reduces rolling resistance; thus, a diesel-powered train is more energy efficient than the equivalent number of road vehicles. In addition, an electric-powered train is not a source of direct emissions of greenhouse gases and other air pollutants, and even indirect emissions can be negligible when the electricity is cleanly produced (Chandra and Agarwal 2007;

Profillidis 2014). Secondly, railways require less land occupancy than other means of transportation, and land use is perhaps the main driver of biodiversity loss globally (Pereira et al. 2012). For example, Profillidis (2014) notices that the "high-speed Paris–Lyon line (a distance of 427 km) occupies as much space as the Paris airport at Roissy." This is not a mere detail; it is already an important issue in highly human-populated areas, and it is becoming important globally as the human population grows and pressure on available arable land increases (Profillidis 2014).

More recently, the protection of the habitats crossed by railways and their wildlife has become a main factor to be taken into consideration when designing new railways or maintaining existing ones (Clauzel et al. 2013; Profillidis 2014), associated with an increased societal awareness of the importance of biodiversity (Pereira et al. 2012). However, compared to other transportation systems, such as roads, less is known about the impact of railways on wildlife, as well as its specificities. Whereas there is a large body of research on road ecology, much less exists on railway ecology (Popp and Boyle 2017). Therefore, as the global railway network increases, and more countries promote railways over road or air transportation of people and goods, we feel that a review of the state-of-knowledge in railway ecology is needed. Railway ecology is an emerging field, but with scarce (and scattered) information about its effects on biodiversity (e.g., Dorsey et al. 2015; Popp and Boyle 2017). This present book deals with the impacts of railways on biodiversity along four main topics: wildlife mortality; habitat loss and exclusion of species from their habitats; barrier effects; and exotic species invasions and impacts of other environmental disturbances caused by railways.

Although railway ecology shares several characteristics with road ecology, it also has some specificities. For instance, traffic on railways tends to be lower than on roads, but the speed of the vehicles can be much greater. Railway ecology can also benefit from studies on the impacts of power lines, these are present in railways when trains are powered by electricity, but their height is usually lower than that of other power lines. Therefore, although railways share some characteristics with other linear infrastructures, they also have some particularities that warrant independent consideration. In this book we highlight the characteristics that railways share with other linear infrastructures, identify which measures can be applied to railways, and show what makes the impacts of railways unique, as well as the required mitigation measures.

The impacts of railways on wildlife have received less attention than those of roads probably because one of its major impacts, vehicle-animal collisions, is not visible to the general public (Wells et al. 1999; Cserkész and Farkas 2015). Ordinarily, only the train crews are aware of the animal mortality caused by collisions, as railway right-of-ways have typically restricted access (Wells et al. 1999). In some cases, researchers have studied the impacts caused by railways combined with those of roads (e.g., Vos et al. 2001; Ray et al. 2002; Proctor et al. 2005; Arens et al. 2007; Li et al. 2010), and some studies have found similar impacts of both networks, namely, wildlife collisions (e.g., Cserkész and Farkas 2015). However, often only the road impacts are highlighted, probably because the road network tends to be more spatially developed than the railway network.

Frequently, roads and railways are co-aligned along the same corridor (e.g., Proctor et al. 2005; Li et al. 2010). In fact, the co-occurrence of roads and railways is an important aspect to have in consideration, as wildlife response to one infrastructure can condition the response to the other. For example, in a study in the USA, Waller and Servheen (2005), found that radio-collared grizzly bears (*Ursus arctos*) crossed a highway-railway corridor at night, presumably to avoid high diurnal highway traffic, but when railway traffic was heavier, there was a behavior that led to higher mortality rates on the railway than on the road. In another study in Canada, Clevenger and Waltho (2005) found that black bears (*U. americanus*) and cougars (*Puma concolor*) tended to cross a highway along wildlife passes far from railway tracks, while wolves (*Canis lupus*) preferred to use crossing structures close to the railway.

It is important to acknowledge the different ways that roads and railways impact wildlife. We consider the following five to be the most relevant: First (1) Traffic flow is much lower on railways, with several case studies showing that the number of trains moving through railways per unit of time are about 0.2–1.6% of the number of cars moving through nearby roads (Gerlach and Musolf 2000; Waller and Servheen 2005; Xia et al. 2007; Kušta et al. 2015); (2) railway traffic flow is characterized by long traffic-free intervals—in some cases there is no nighttime railway traffic (e.g., Rodríguez et al. 1997; Pérez-Espona et al. 2008)—although noise and vibrations produced by trains are higher than those produced by cars (Dorsey et al. 2015; Kociolek et al. 2011); (3) railways have lower wildlife mortality, possibly because of lower traffic flow (Cserkész and Farkas 2015; Kušta et al. 2015), but this assertion should be taken carefully, because figures for roads may be inflated as they are far more widespread than railways (Pérez-Espona et al. 2008; Yang et al. 2011) (4) railway corridors are narrower than those of roads, which imply lower loss of habitats when a new line is built (e.g., Gerlach and Musolf 2000; Tremblay and St. Clair 2009); finally, although some maintenance practices that use pollutants (potential disturbers) are shared by railways and roads, like de-icing or the application of herbicides on verges, the impact of vehicles, the most important source of chemical pollutants (Forman et al. 2003), is lower in railways because many trains have electric engines.

Especially interesting for our purposes are the studies comparing railway impacts with those of roads, as they highlight their similarities and differences. These differences and similarities, however, tend to be species-specific. For instance, Gerlach and Musolf (2000) found that in Germany and Switzerland, a 25-year-old highway contributed to genetic substructuring in bank voles (*Clethrionomys glareolus*), while a 40-year-old railway and a 25-year-old country road did not. In a similar vein, railways seemed to have no strong effects on the red deer (*Cervus elaphus*) population's genetic differentiation in the UK, as differentiation was the same with or without railways, while roads were identified as gene-flow barriers to this species (Pérez-Espona et al. 2008). Railways had a low impact is the latter example probably because they were not parallel to orographic barriers, they were relatively sparse, and they had a low traffic flow (Pérez-Espona et al. 2008). In tune with the previous work, Yang et al. (2011) found that roads contributed to the genetic isolation of Chinese populations of Przewalski's gazelles (*Procapra przewalskii*), but railways had no influence on genetic differentiation, probably because of their low traffic flow and the presence of wildlife passes. A similar result was found for roe deer (*Capreolus capreolus*) in Switzerland, although in this case, the authors suggested that the differences could be due to highways being fenced and railways not, as traffic flow was similar (Hepenstrick et al. 2012). In Canada, Tremblay and St. Clair (2009) showed that railways were more permeable to forest song bird movements than were roads, likely due to their narrower width and lower traffic. Indeed, the authors found that the gap size in the vegetation was the most important factor constraining forest bird movement, especially when the gap was larger than 30 m. As a final example, in their study of New England cottontails (*Sylvilagus transitionalis*) in the USA, Fenderson et al. (2014) concluded that major highways limited dispersal, whereas railways and power lines corridors acted as dispersal facilitators.

Railways are more environmentally friendly than road vehicle transportation, but this does not mean that their negative impacts should be ignored. Therefore, while acknowledging that there is a wide range of situations where priority should be given to the development of railways, or to the maintenance of existing ones, it is also crucial to take into account the impacts on the habitats transversed by these infrastructures, and on the wildlife populations occurring therein. However, we believe that these impacts can be considerably reduced once they are identified, and once the decision-makers are willing to pursue the required mitigation measures. In the next chapters, we will first review the impacts of railways on biodiversity (mortality, exclusion and barrier effects, introduction and dispersal of exotic species and pollution) and then present several case studies with a view to identifying problems and proposing strategies to mitigate railways negative effects.

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