

# Chapter 19

## What's Next? Railway Ecology in the 21st Century

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*Predicting is very difficult, especially about the future, attributed to Niels Bohr.*

**Abstract** As societies realise the importance of maintaining biodiversity and, accordingly, acknowledge the need for monitoring, minimizing and compensating the impacts of socioeconomic activities, including transportation, more scientists will be called to address these societal challenges. Railway Ecology is emerging in this context as a relatively new field to identify and provide solutions to the specific environmental problems associated with the building and operation of railways, particularly their impacts on wildlife. This is an interdisciplinary field that uses and draws methods from other disciplines, ranging from ecology and genetics, to statistics and computer simulations. Here, we summarize the guidelines to address railway-related biodiversity conservation problems as they were identified in the several chapters of this book, and recommend lines for future research.

**Keywords** Climate change · Environmental sustainability · Linear infrastructures · Railway ecology

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## A Bright Look at the Future of Railways

Transportation in the 21st century involves multiple challenges. Transports will have to deal with the increasing needs of a growing and wealthier human population, and the socioeconomic requirements to deliver natural resources, manufactured goods, and transport people. The emergence of new strong economies, and the expectation that economic growth will raise the living standards of vast populations, will be surely accompanied by an increase in transportation infrastructures, given the well-known relationship between transportation activity and Gross Domestic Product (GDP) (Profillidis 2014). How societies will accommodate economic development with the biophysical constraints imposed by the environment is a major challenge, but one where railways will certainly play an important role (Smith 1998, 2003).

One of the reasons to expect a steady development of railways is related to their cost-effectiveness over other means of transportation, particularly for the so-called intermediate range distances (Profillidis 2014). Therefore, it is expected that railways will develop to fill in the niche that lay somewhere in-between the local door to door transportation and, in the other extreme, the long distance transportation of passengers or freight that is better accomplished through aviation or marine transportation. The exact level at which railways will fill in such niche, however, will depend on the characteristics of the region where they operate: its geography, the size of its population and how the population is distributed. Nevertheless, it is likely that in many countries new railway lines will be built and others will be improved, to support, for instance, the commuting of people between the suburbia and city centres, to transport passengers among cities laying a few hundred kilometres apart, and to transport freight among harbours and big cities.

Another reason to expect the expansion of railways is related to its environmental benefits relatively to other means of transportation, which is well illustrated by the role it can play in addressing global warming. For instance, Dulac (2013) analysed infrastructure requirements under different climate change scenarios, concluding that an increase in 335,000 railway track kilometres would be needed to accommodate the projected transportation needs until 2050, while keeping the increase in average global atmospheric temperatures under 4 °C. Under a more strict policy scenario of a 2 °C increase in temperatures, the railway network would have to expand by approximately 535,000 track kilometres, reflecting the higher efficiency of railway over road transportation (Dulac 2013). Once again, this will certainly lead to a steady development of railway networks, thereby calling for the collaboration of railway ecologists to mitigate impacts and to foster the environmental added value of railways.

## Emerging Trends and Challenges

While we expect a major development in railway networks in the next decades, technological developments may considerably affect their characteristics, as well as the environmental problems that will be raised. For instance, in regions with high

population densities the use of the magnetic levitated (“maglev”) trains may become a typical feature (Najafi and Nassar 1996), but some of the problems associated with barrier effects and mortality are still likely to occur. Although maglev trains share several of the characteristics with the present railways, other technologies such as the admittedly farfetched “hyperloop” may differ considerably (Matthews and Brueggemann 2015). In a hyperloop, passengers and freight travel in vehicles enclosed in elevated “tubular” structures. In this case, barrier effects will be greatly reduced, and mortality due to collisions with the trains will disappear, though the possibility of flying animals colliding with the tubular structure will still exist. Another technological advancement that is likely to develop in forthcoming years is electric cars with auto-pilot features. As we write, this technology is being promoted by large companies (e.g., Google) and at least one company already commercializes cars with hardware and software enabling the auto-pilot mode (Tesla Motors), a development that services such as Uber may use automated in the future. These vehicles, or future improved versions, may enable comfortable travels with the flexibility of door to door connections, challenging some of the advantages that trains presently exhibit for some distances. Nevertheless, it is unlikely that railway transportation as we know it today will become obsolete at any time in the near future, requiring a continued engagement of railway ecologists to deal with the current and future challenges associated with this transportation system.

Despite its positive prospects at the global scale, however, it is likely that some railway lines will get out of operation due to technological developments and changes in socioeconomic requirements, as it has happened during the past decades. For instance, railways in the USA after World War II were quickly put aside in favor of other means of transportation of passengers, such as automobiles and airplanes, and by 1990 the 270,000 miles of active rail lines had diminished to 141,000 miles (Ferster 2006), though railways have retained 43% of the freight market (Profillidis 2014). Comparable processes have occurred in other countries such as Portugal, where many lines built during the early twentieth century lost their importance and were progressively abandoned during the second half of the twentieth and early twentyfirst centuries (Sarmiento 2002). These changes represent opportunities for conservation and call for the active participation of railway ecologists in collaboration with other specialists, as abandoned railway lines may lead to ecologically-oriented projects as well as to the mitigation of situations of social injustice. The combination of ecological and social minded policies can contribute to a new global pattern of urban transformation, as exemplified by the High Line in New York City or the Sentier Nature in Paris (Foster 2010). The old High Line railroad was disused in 1980 and it then started to develop as a semi-natural habitat that was converted into a public park comprising twenty-two blocks along the lower west side of Manhattan (Foster 2010). Paris’ Sentier Nature represents another approach, where an old railway was converted into a nature trail, now enriched with a diversity of types of ecosystems, with 200 species of flora and 70 species of fauna (Foster 2010). Although this field of ecological restoration after railway abandonment was not dealt with in this book, this is an important area

where the experience on linear infrastructures of railway ecologists may prove instrumental, namely due to their knowledge on the species and habitats that can persist in railway verges in urban and suburban settings (see Chap. 16).

## Railways Travel Towards Environmental Sustainability

As with any other means of transportation, there are environmental issues associated with railways, ranging from wildlife mortality, barrier effects, introduction of exotic species, and several forms of pollution. Some of these are comparable to those found in roads and other linear infrastructures, while others are railway specific. Likewise, some mitigation measures can be adapted from road and power line infrastructures, while others have to be developed specifically for railways. As highlighted throughout this book, information is still in short supply for the evaluation and mitigation of impacts specific to railways, which justifies the need to continue investing in research programs targeting railway ecology on its own right. Based on the collective experience of this book we suggest that the following research lines should be the priority focus of such programs, which will greatly contribute to help keep railways on track towards environmental sustainability:

- First and foremost, studies to evaluate the biodiversity impacts of railways and their mitigation measures need in most cases to be strengthened through the use of adequate designs, sufficiently large sample sizes, and sufficiently long time frames. Ideally, BACI (Before-After-Control-Impact) designs should be used to examine such impacts, avoiding simple designs that have little power to demonstrate causality (Balkenhol and Waits 2009; Corlatti et al. 2009; Soanes et al. 2013; see Chap. 12). Monitoring must be long-term, as some species need time to get used to disturbances associated with railway operation, and to the implementation of mitigation measures (Baofa et al. 2006; Yang and Xia 2008; Corlatti et al. 2009; Soanes et al. 2013).
- Second, we still need better estimates of wildlife mortality in railways, though this is one of the most visible and well-studied impacts. Tackling this problem will require, for instance, field experiments on searcher efficiency and carcass persistence on railways (Barrientos et al. in review). These are expected to be railway-specific because, as commented in Chap. 1, traffic flow on railways is markedly lower than that of roads. This is important because low traffic flows allow time gaps for scavengers to have access to carcasses. On the other hand, trains travel over rails, and corpses falling out of them can persist longer as there is no flattening as it may happen in roads.
- Third, we need a better understanding on the barrier and fragmentation effects of railways, and how these may act together with those of other linear structures such as roads (see, e.g., Chap. 14). Concurrently, we need to know where, when and how can wildlife passes effectively mitigate such barrier and fragmentation effects, by helping to restore connectivity across the landscape. A range of

studies may contribute to such understanding, including comparisons of wildlife crossings of railways before and after the building of wildlife passes, in places with and without such passes (i.e., BACI designs; Corlatti et al. 2009; Soanes et al. 2013). Novel molecular techniques may also contribute to tackle these issues, using for instance non-invasive genetics to know which individuals cross the railways and how railway barriers contribute to spatial genetic structuring (Riley et al. 2006; Balkenhol and Waits 2009; Clevenger and Sawaya 2010; Simmons et al. 2010; see also Chap. 4). Modelling approaches may also be useful to explore the demographic and genetic consequences of barrier effects induced by railways, and to disentangle barrier from mortality effects (Borda-de-Água et al. 2011, 2014; Ceia-Hasse et al. 2017).

- Fourth, we need to know if and how mortality and barrier effects translate into population effects, which in turn can affect the persistence of vulnerable species around railway corridors (van der Grift 1999; Dorsey et al. 2015). This might be achieved through population modelling approaches similar to those already used in road ecology (Taylor and Goldingay 2009; van der Ree et al. 2009; Borda-de-Água et al. 2014; Ceia-Hasse et al. in review). The development of these models require careful field studies whereby critical information on fecundity, survival and dispersal are estimated, which can then be used to estimate the conditions under which population viability may be affected by railways. Due consideration should also be given to age- and sex-specific demographic parameters, as huge variation in population responses may occur if mortality affects primarily non-breeding versus breeding individuals, or males versus females. Molecular methods may also contribute to understand population responses to railways, either by helping to estimate population parameters, or to evaluate changes in effective population sizes in relation to mortality and fragmentation effects (Balkenhol and Waits 2009).
- Fifth, we need studies on railway ecology focusing on a wide range of species, which should be representative of life history and behavioural traits potentially affecting vulnerability to railways. To date, most research has focused on species with high socio-economic profile, like large charismatic mammals, or on those with limited mobility, like herptiles (van der Grift 1999; Dorsey et al. 2015). Broadening the scope of research is important, because mitigation measures designed for some species may be inappropriate for others, thus requiring informed adjustment based on scientifically sound information (Clevenger and Waltho 2005; Morelli et al. 2014; Vandeveldt et al. 2014; Wiacek et al. 2015; see Chap. 16). To forecast impacts on species with differential traits, pilot field studies and a systematic review of the available evidence should be carried out to investigate what are the key ecological traits, such as dispersal ability or generation time, affecting population responses to railways.
- Finally, there are a number of important issues that remain poorly explored, despite their potential importance to the environmentally-sound management of railways. For instance, little is known about the consequences of vibration and noise on biodiversity living adjacent to the railway bed (see Chap.6). Also, studies are needed on the relative cost-effectiveness of different management

tools and mitigation measures to help reconcile environmental protection and socio-economic demands (see, e.g., Andreassen et al. 2005; Ford et al. 2009; Mateus et al. 2011). The potential positive impacts of railways also need to be better explored, including in particular the prospective for the right-of-way to act as a shelter for biodiversity (see Chap. 16), which can probably be improved through well-designed wildlife-friendly management procedures.

## Final Remarks

Overall, our book documents the wealth of research that is already available on the ecology of railways, particularly on the evaluation and mitigation of impacts on wildlife, illustrating the considerable progress that has been made over the past decade. However, it also shows that many aspects of railway ecology remain poorly researched, which makes it difficult to understand what are the main impacts of railways on important dimensions of biodiversity such as landscape connectivity and population viability. As a consequence, the evaluation and mitigation of railway impacts continue to be largely driven by the lessons gained from road ecology, which may often be inadequate for application in the railway context. By reviewing the state-of-the-art and presenting a diversity of valuable case studies, we hope that this book can contribute to attract both researchers and practitioners to this interesting field of applied science, thereby promoting the development of new tools and applications for a better integration of the transportation networks with the challenges associated with the protection of biodiversity.

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