HANDBOOK OF ROAD ECOLOGY
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WILEY Blackwell
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Dr Suzanne J. Milton is a plant ecologist and research associate of the Percy FitzPatrick Institute, University of Cape Town. After retiring from academia, she started an indigenous nursery and ecological consulting and restoration business in the arid Karoo region of South Africa with Richard Dean. See http://renu-karoo.co.za/. Sue Milton and Richard Dean also founded the Wolwekraal Conservation and Research Organisation.

Mike Misso has been the Manager of Christmas Island and Pulu Keeling National Parks since late 2010. Prior to moving to Christmas Island, Mike worked as a Natural Resource Management facilitator, and prior to this in a range of national park management roles at Kakadu and Uluru Kata Tjuta National Parks in Australia, including as a Planning Officer, Chief Ranger and Natural Resource Manager.

Christa Mosler-Berger is a wildlife biologist and co-manager of the non-profit association WILDTIER SCHWEIZ and responsible for the Swiss Wildlife Information Service. She has been involved in the evaluation of animal detection systems (ADS) since they were first installed in 1993 in Switzerland.

Rob Muller has worked as the Chief Ranger of Christmas Island National Park since mid 2010. One of Rob’s key responsibilities is, with other Ranger staff, to coordinate the road management activities for conserving red crabs during their annual breeding migration. Prior to moving to Christmas Island, Rob worked as a Ranger (including as a Chief Ranger), at Kakadu National Park in Australia for over 20 years.

Benezeth Mutayoba is an awardee of 2014 National Geographic/Buffett Award in ‘Leadership in African Conservation’ and works on wildlife movements, road kill dynamics, connectivity and gene flow in isolated wildlife populations as well as on wildlife health and forensics. He is a professor in the Department of Veterinary Physiology, Biochemistry, Pharmacology and Toxicology, Faculty of Veterinary Medicine, Sokoine University of Agriculture, Tanzania.

Katarzyna Nowak has studied primates and elephants in flooded and montane forests in Tanzania and South Africa. She is currently a junior research fellow at Durham University, UK, and a research associate at the University of the Free State, Qwaqwa, South Africa. She is interested in how flexibility in behavior affects species’ capacity for persistence in human-dominated landscapes. She is currently researching samango monkeys’ landscape of fear.

Kirk A. Olson has been promoting conservation of migratory ungulates and grazing ecosystems in Mongolia and Central Asian region since 1998. Kirk
completed his PhD at the University of Massachusetts, Amherst, and his dissertation focused on the ecology and conservation of Mongolian gazelles. Kirk is a Research Associate at the Smithsonian Conservation Biology Institute and most recently worked with Fauna and Flora International’s saiga conservation program.

Mattias Olsson has a PhD in biology and is working at EnviroPlanning AB and part time at SLU (Swedish University of Agricultural Sciences) in the Triekol research program. His research and enquiries are about wildlife and infrastructure, and he regularly works with civil engineers and landscape architects in order to mitigate the negative effects of highways and railroads. When he is not working, he spends time with the family and as a coach for a girl’s handball team and a boy’s soccer team.

Fabrice Ottburg, BSc, is a research scientist involved in applied and multi-disciplinary research, consultancy and acquisition for various projects in ecology (fundamental ecological research) and habitat fragmentation. He has extensive experience in ecological impact assessments in landscape areas and mitigation/compensation/monitoring studies for large-scale projects. He is also qualified in studies on nature development, ecological nature and juridical development and animal ecology (fishes, amphibians and reptiles).

Eugenia Pallares is General Director of the Mexican conservation NGO Jaguar Conservancy. She has collaborated and coordinated various projects on the conservation of jaguars and their habitat in Mexico, mitigation of the impact of roads on biodiversity in the Mayan Forest, and projects involving environmental policies. She has worked on editorial boards where a number of books, calendars, brochures and other materials have been produced. She is also a member of the Board of the Council for Sustainable Development in Mexico.

Dr Dan Parker is a wildlife biologist, based at Rhodes University in Grahamstown, South Africa. He supervises a large and vibrant post-graduate research school and is particularly interested in the biology and conservation of Africa’s large carnivores.

Dr Kirsten M. Parris is a Senior Lecturer in the School of Ecosystem and Forest Sciences, The University of Melbourne. Her research interests include the ecology of urban systems, ecology and conservation biology of amphibians, bioacoustics, field survey methods and ecological ethics.

Ms Claire Patterson-Abrolat runs the Endangered Wildlife Trust’s Special Projects Programme which covers a range of projects dealing with the development of innovative, economically viable alternatives to address harmful impacts to the benefit of people and biodiversity.

Sarah E. Perkins is a Lecturer in Ecology at Cardiff University. Sarah established and runs ‘Project Splatter’ a UK-wide citizen science initiative to collate wildlife roadkill using social media. Sarah is a strong supporter of the value of crowd-sourced data to both scientists and citizens. Away from roads her research focuses on the ecology of wildlife diseases.

H.C. Poornesha works on conservation of wildlife habitats in the Western Ghats of India through GIS analysis and conservation planning. He has also contributed largely to applied conservation issues in the landscape (see http://ncf-india.org/people/h-c-poornesha for further details).

Roger Prodon is a professor at the École Pratique des Hautes Études (EPHE) where he led for 12 years a research team working on vertebrate ecology in Mediterranean and mountain areas. He is mainly interested in bird community dynamics following disturbance (e.g. after fire), long-term monitoring, bird elevational gradients and island ecology.

Dr Asha Rajvanshi heads the EIA Cell of the Wildlife Institute of India (WII). She works in the area of road ecology and has developed a range of best practice guidance manuals for mainstreaming biodiversity in impact assessment in different economic sectors including roads. She has been part of several global EIA initiatives and is a member of IAIA.

Dr Lisa J. Rew is an associate professor at Montana State University. Her research concentrates on the dispersal, distribution and dynamics of weedy plant species, and how best to manage them at a local scale. She is involved with this project due to her interest in how seeds are dispersed by vehicles, and how that could impact wildlife. When she isn’t working she can often be found playing in the mountains.

Kevin Roberts is currently the Section Leader – Environment with consulting firm Cardno. From 2007 until 2014, he was the Senior Environmental Specialist (Biodiversity) for the NSW Roads and Maritime Services, Australia. Kevin’s responsibilities were developing policy and procedures for managing biodiversity across the
organisation. Prior to working for RMS, Kevin has held a range of senior roles in the NSW agencies responsible for regulating and planning for biodiversity conservation.

Dr Carme Rosell is a senior consultant at Minuartia and is part of a research group at the University of Barcelona. She has led numerous projects to design and monitor wildlife passages in roads and high speed railways. Her recent projects are focused on reducing animal-vehicle collisions and improving road maintenance practices. She has co-authored guidelines including the COST341 handbook Wildlife and Traffic. Carme is a member of the Infra Eco Network Europe Steering Committee.

Trina Rytwinski is currently working as a post-doc in the Geomatics and Landscape Ecology Research Lab, at Carleton University, Ottawa, Canada. Her research focuses on understanding the circumstances in which roads affect population persistence, specifically looking at species traits and behavioural effects of roads, and ways to mitigate road effects.

Thomas W. Seamans, MS, serves as a supervisory wildlife biologist for the NWRC. His primary research focus is the development and evaluation of wildlife repellents and methods intended to reduce human–wildlife conflicts.

Helio Secco is biologist who graduated from the State University of Northern Rio de Janeiro (UENF), and obtained his MSc in Applied Ecology at Federal University of Lavras (UFLA). In recent years, he participated in several projects at the Brazilian Center for Research in Road Ecology. Helio is currently interested in research areas related to the assessment of environmental impacts of anthropogenic structures on tropical wildlife.

Dr Andreas Seiler received his PhD in wildlife biology in 2003 from the Swedish University of Agricultural Sciences. Since 1994, he has been working on traffic and wildlife related issues, mainly research on animal–vehicle collisions and traffic-related mortality and barrier effects, and broader landscape fragmentation issues. He has been active in COST-341 action and is a member of the Steering Committee and Secretariat of IENE (Infra Eco Network Europe) with a special responsibility for the IENE international conferences.

Dr Nuria Selva is an associate professor at the Institute of Nature Conservation in Krakow, Polish Academy of Sciences. Her research within animal ecology is broad, including large carnivores and scavengers, and conservation biology. She has recently focused on brown bears in the Carpathians, as well as the effects of supplementary feeding and global change on this bear population. She also focuses on conservation policies at European and international levels to protect ecological processes and wilderness, including roadless areas.

K. S. Seshadri is pursuing his PhD in biology at the National University of Singapore. He has varied interests spanning birds, herpeto-fauna and canopy science. He is a recipient of the ‘Future Conservationist’ award and is actively involved in conservation, education and outreach activities. Though he primarily studies amphibians, he has studied the impact of roads on fauna in south India. He is passionate about bird watching and nature photography.

Fraser Shilling is the Co-Director of the Road Ecology Center and research scientist in the Department of Environmental Science and Policy, University of California, Davis. He obtained his ecology-focused Ph.D. from the university of Southern California. He is a member of several Transportation Research Board committees and leads road ecology research for state and national transportation agencies. He is the lead scientist for wildlifeobserver.net and wildlifecrossing.net, both crowd-sourced datasets for wildlife observation. He also leads research in intermediate-scale monitoring of sea level rise and infrastructural adaptation.

Leonard E. Sielecki is the Wildlife and Environmental Specialist for the British Columbia Ministry of Transportation and Infrastructure. Since 1996, Leonard has been the Province of British Columbia’s subject matter expert on wildlife accident monitoring and mitigation. He serves on committees of the National Academies of Sciences, the Transportation Research Board, and the International Conference on Ecology and Transportation (ICOET). Leonard is completing his PhD at the University of Victoria where he developed the Wildlife Hazard Rating System® for motorists.

Anders Sjölund is the National Biodiversity Coordinator for the Swedish Transport Administration. He is also Chair of the nature and cultural heritage group at The Nordic Road Association (NVF), Chair of the Steering Committee for the Infra Eco Network Europe (IENE), member of the Swedish Wildlife Accident Council and member of the Steering Committee for the International Conference on Transport and Ecology (ICOET).
Dr Daniel J. Smith is a research associate and member of the graduate faculty in the Department of Biology at the University of Central Florida and a member of the National Academies Transportation Research Board Subcommittee on Ecology and Transportation. He has over 20 years of experience in the fields of ecology and environmental planning. His primary focus is studying movement patterns and habitat use of terrestrial vertebrates and integrating conservation, transportation and land-use planning.

Kylie Soanes is a PhD candidate at the University of Melbourne, Australia, and is part of the Australian Research Centre for Urban Ecology and the Australian Research Council Centre for Excellence in Environmental Decisions. Her PhD project evaluates the effectiveness of wildlife crossing structures for a gliding marsupial over a major highway. Kylie is interested in evaluating the success of conservation management and restoration projects and designing effective monitoring programs.

Josie Stokes is the Senior Biodiversity Specialist (Environmental Policy) at the NSW Roads and Maritime Services (RMS). Her role is to develop operational environmental policy to assist the RMS in minimising its impact on the environment, review environmental impact assessments and provide expert technical advice to project teams. She has also been an ecologist for the Australian Museum and Parsons Brinckerhoff. She has over 17 years of experience in assessing the impacts of development, particularly of linear infrastructure, on biodiversity across Australia.

Dr Emma Stone is a Research Associate in the Bat Ecology and Bioacoustics Lab at the University of Bristol, UK. She conducts experimental research on the impacts of roost exclusions and the effectiveness of mitigation for bats. Her PhD was on the impact of street lighting on bats and the effectiveness of mitigation legislation for bats. Emma is now conducting applied research on the conservation of bats and carnivores in Malawi and has established the charity Conservation Research Africa to assist.

Martin Strein is a biologist with the German Federal state of Baden-Württemberg who is advising on the implementation of a statewide biotope network. When focusing on wildlife mitigation measures, he uses a broader ecological perspective, rather than a species-specific solution, to support important ecological functions and biodiversity. He is also skilled in the management of large protected areas and has spent many years working for and evaluating national parks, mainly in Africa.

Richard P. J. H. Struijk is a herpetologist at RAVON Foundation (Reptile Amphibian and Fish Conservation, the Netherlands) and is graduate faculty at the Wageningen University and Research Centre. Coordinating several monitoring projects on the use of crossing structures by herpetofauna, he is involved in infrastructural planning and evaluation of mitigation measures. Privately he is working on the conservation and captive propagation of endangered Asian box turtles (Cuora sp.).

Paul Sunnucks is a researcher and educator in the School of Biological Sciences at Monash University, Australia. His research interests focus on population biology of animals in natural habitat and those altered by human activities, working with stakeholders to manage landscapes and ecological processes. He has a particular fondness for all ecosystems and life forms.

Adam Switalski is Principal Ecologist for the environmental consulting company, Inroads Consulting LLC. He specializes in the management of forest roads and is an expert in road restoration science and practice. His research is focused on the impact of restoring roads on fish and wildlife habitat. He is working to establish more cost-effective and ecologically sustainable transportation systems in the US Northern Rockies.

Stephen Tonjes has worked 28 years in environmental compliance for the Florida Department of Transportation, and now consults part-time. Before FDOT, he served in the US Coast Guard, taught marine science in the Florida Keys, and monitored compliance for the Coast Guard bridge permit program in Juneau, Alaska, and for the US Fish and Wildlife Service in Washington, DC. He has a special interest in communicating wildlife ecology to transportation professionals and transportation development to wildlife ecologists.

Marguerite Trocmé has been responsible for setting the environmental standards for the Swiss highways since 2008 at the Federal road office. She began working on roads and environmental issues in 1989 as an environmental project reviewer at the Swiss federal office for the environment. She was vice-chairman of the European COST 341 project on habitat fragmentation due to transport infrastructure and is currently president of the VSS commission on traffic and wildlife and has initiated a number of research projects in the field.
Edgar A. van der Grift is a senior research scientist in the Environmental Science Group at Alterra, part of Wageningen University and Research Centre. His research focuses on the impacts of habitat fragmentation on wildlife and the effectiveness of measures that aim to restore habitat connectivity across roads and railroads. He also consults to policy makers, road planners and conservation groups during the preparation and implementation phase of projects that aim for the establishment of effective ecological networks and environmental friendly transport systems.

Dr Rodney van der Ree is an Associate Professor and the Deputy Director of the Australian Research Centre for Urban Ecology, a division of the Royal Botanic Gardens Melbourne, based at the University of Melbourne. His research broadly focuses on quantifying and mitigating the impacts of human activities, such as roads and cities, on the natural environment. He is currently leading research projects on the effectiveness of mitigation techniques for wildlife in south-east Australia and is interested in road ecology issues in developing countries.

Paul J. Wagner is a wildlife ecologist with the Washington State Department of Transportation, Washington, USA. Active with Road Ecology for over 20 years, he serves on research committees of the National Academies of Sciences, the Transportation Research Board Committee on Ecology and Transportation and the Infra-Eco Network Europe (IENE). Paul is a founding member and past Chair of the International Conference on Ecology and Transportation (ICOET).

Dr Yun Wang is an associate professor at the China Academy of Transportation Sciences (CATS). He obtained his PhD from the China Academy of Sciences in road, landscape and ecological protection in 2007. In 2005, he translated Road Ecology: Science and Solution by Richard Forman into Chinese and in 2009, he co-wrote Road Ecology in China. His research now focuses on the interactions of roads and wildlife, landscape fragmentation and road ecology.

Susie Weeks has been the Executive Officer of the Mount Kenya Trust since 2001. She and her team have managed a number of successful private–public conservation partnerships to protect the integrity of Mount Kenya’s forests and wildlife. The Mount Kenya Trust spearheaded the pioneering Mount Kenya Elephant Corridor project alongside the project’s partner organisations. Susie is a gazetted Kenya Wildlife Service Honorary Warden.

Cameron Weller is an environmental manager with Jacobs and has over 7 years experience, primarily in the delivery of large infrastructure projects in Australia. He also has experience in working on large multi-disciplinary design teams as the environmental design lead. His work involves designing and managing the installation of fauna mitigation measures, writing environmental management plans and ensuring environmental compliance.

Patricia White began the US Habitat and Highways Campaign in 2000 to address impacts of highways on wildlife and encourage transportation planning that incorporates conservation. Her first report, Second Nature: Improving Transportation without Putting Nature Second was awarded the 2004 NRCA Award of Achievement for best publication. Patricia was a founding member of the International Conference on Ecology and Transportation (ICOET) Steering Committee, a founding member of the TRB Committee on Ecology and Transportation and proud founder of the TransWild Alliance.

Brendan Whittington-Jones is currently based in Oman and authoring a book on African wild dog conservation in South Africa. During his seven years working at the Endangered Wildlife Trust he coordinated the KwaZulu-Natal Wild Dog Advisory Group and the National Wild Dog Metapopulation Project. His MSc focused on the conservation and conflict implications of wild dogs ranging outside of protected areas in KwaZulu-Natal province, South Africa.

Fernanda Zimmermann Teixeira is a biologist interested in conservation biology, applied ecology and EIA. She is a PhD student in ecology at Federal University of the Rio Grande do Sul State (UFRGS) in Brazil, studying spatial patterns of wildlife–vehicle collision and impacts of road networks on the landscape. During her Master’s research, she studied the similarity of road-kill hotspots among different groups and the influence of carcass removal and detectability on road-kill estimates.
Roads smoothly and efficiently move us from place to place, and, by concentrating movement in somewhat straight strips, limit the big footprint of impacts on nature. But most roads were built before the rise and spread of ecology through society. As a consequence in part, roads with traffic cause significant and widely permeating effects on natural systems. Mitigation of today’s surface transportation system therefore stands as a primary challenge of society and transportation. Furthermore in rapidly developing areas worldwide new roads proliferate, which now can be built with solid ecological foundations.

Nature within the strip of road and roadside is, of course, degraded. Mitigation reduces that effect, but especially minimizes the outward-ripping degradation across the land. What nature is affected, or natural systems disrupted? Three dimensions are central: (1) habitat and plants, (2) water quantity and quality and (3) wildlife. Roads and wildlife are the highlight of this book, though valuable insights on the other two dimensions appear.

The pages in your hand are a tour-de-force, a gem, indeed a treasure chest. I find it readable, interesting, practical, useful and ambitious. The remarkable cast of authors has uncovered a goldmine for us. The editors catalysed extra rigor and consistency, thus encouraging comparisons and usability. Virtually, every chapter begins with several succinct topic statements, which pinpoint the essence and also provide an overview. These statements are then analysed as the sections of text. Mitigation is the focus, though new road construction in developing nations is included. Wildlife, including different faunal groups and different regions, is emphasised. An international perspective thoroughly permeates the presentation. Policy, planning and practice are highlighted alongside research and state-of-the-science results. I gained insight into every chapter perused.

Building on this accomplishment, analogous books highlighting roads and vehicles relative to vegetation and water would be valuable. Habitat, vegetation and plants are emasculated by roadside cutting and mowing. Fortunately, converting most (though not all) roadside area from grassy to woody vegetation is consistent with traffic safety and cost efficiency. Consider the numerous ecological and societal benefits. New habitat created, and existing adjacent woody habitat enhanced. Wildlife populations increased, probably well exceeding any increase in roadkills. Road crossing facilitated, thus reducing the habitat fragmentation and barrier-to-movement effect against wildlife and pollinators. There was reduced spread of airborne chemical pollutants from roadway and vehicles. Rare plants, animals and habitats enhanced on roadsides, especially important where scarce in agricultural and urban landscapes. Water in varied forms poses endless problems, both familiar and as surprises, for transportation. Think of road-closure flooding, washouts/roadbed failures, wet driving surfaces, drainage-ditch filling, eroded roadsides, mudslides/landslips, frost cracks and potholes, snow-and-ice surfaces, blowing snow and too much snow. Water quantity-and-quality problems for nature are also severe. The soil water table is widely altered (raised or lowered) by roads. Where the water table is close to ground surface, wetlands are altered (drained or expanded). Fortunately, ‘eco-piping’ or permeating the roadbed with pipes crossing beneath a road maintains more natural water tables and wetlands. With permeated roadbeds, floodwaters seldom reach road
surfaces and rarely wash out roads. The hydrologic connectivity through roadbeds supports more natural fish movements, and happy anglers. The same pipes connect the land for many small terrestrial animals. Drilling and inserting horizontal pipes is a routine, and in view of this array of benefits, cost-effective technology.

Water-quality pollution benefits follow suit. Most vehicle- and road/roadside-generated chemicals are readily ‘treated’ near roads in elongated mitigation structures (depressions, wetlands, ponds). Soil and microbes mainly clean the water. Polluted heated ditch-water entering nearby water bodies is largely eliminated using familiar stream features (convoluting, step-damming) plus tall vegetation (wind-and-sun evapotranspiration pumping). Again these manifold water quantity and quality benefits are consistent with safety and efficiency, cost effectiveness, and engineering design creativity.

A decade ago, four transportation leaders, a leading hydrologist, and nine ecology-research scholars co-wrote the book, *Road Ecology: Science and Solutions*. This synthesized a scattered literature and articulated principles linking roads/vehicles, soil/water/air and plants/animals. One of our dreams was the highly useful compendium now in your hand.

The scientist in me inexorably jumps from this treasure chest of insight to pregnant and important research frontiers awaiting us. How do our current ecological science results apply to the diverse types of roads and traffic levels criss-crossing the land? The ecology of road segments and especially road networks in a landscape cries out for study. Where is the ecology of different truck, car, tire, even road surface types? What is the (ecology and cost) optimum distance between road-crossing structures for different wildlife types? How can the ubiquitous utility poles along roads be used in mitigation solutions? To understand roads and wildlife populations, the non-roadkill dimensions now need much greater emphasis. As suggested earlier, habitat/plant and water quantity/quality dimensions of road ecology are lurking giants, awaiting a few prescient researchers and leaders.

My government-and-citizen-side hones in on the need and opportunity to accelerate solutions now for transportation, the land and us. Every roadbed, bridge and culvert repair/replacement is the cost-effective moment to concurrently address other goals of society, such as walking/biking paths, reduced flooding, enhanced fish movement, reconnected split communities and so forth. Roadsides represent a massive little-used resource (for nature and us) at our doorstep. Roadside food production, trail networks, stormwater and pollution mitigation, history-and-nature education effectively create variegated roadsides, bulging with useful solutions for society. Light, noise, vibration and wind can be dispersed or concentrated, as well as decreased or increased. Eco-piping or pipe-perforated roadbeds provide lots of benefits quickly. The ‘road-effect zone’ provides a ready framework for ecologically planning, engineering and mitigating roads. In parks, towns and sprawl areas, curvy, slightly bumpy and seemingly narrow roads slow traffic and reduce effects on wildlife. In every jurisdiction, remove a road segment or two to create continuous ecologically valuable, large natural-habitat patches. By lowering (e.g. 2–3 m) short stretches of roads in good-drainage areas, inexpensive green-bridges (with some 10 cm of sandy soil) will help re-establish semi-natural wildlife movement patterns across the land. And just on the horizon, a transportation system slightly above or below ground level, using lightweight renewable-energy automated pods, effectively recovers an extensive area of road/roadside-covered terrain. Furthermore this ‘netway system’ reconnects today’s fragmented land for nature and us. Indeed, on an exhilarating netway ride at London’s airport I experienced the future.

Road ecology and this book’s impressive synthesis highlight a great opportunity for planners, engineers and ecologists to collaborate for new successes, and receive important accolades together. History will record that transportation, land-and-water, and society are the big beneficiaries.

Richard T. T. Forman
Harvard University
This book brings together some of the leading researchers, academics, practitioners and transportation agency personnel from around the world to focus on the challenge of improving the ecological sustainability of the linear infrastructure – primarily road, rail and utility easements – that dissects and fragments most landscapes around the world. Where possible, we aimed to have co-authors from different continents on every chapter – and indeed, many authors are collaborating together for the first time on this book.

When authors were invited to contribute, we gave them this initial challenge: ‘Imagine you are in charge of your professional world for a day, and could change anything to improve the ecological sustainability of roads (or other linear infrastructure) and traffic: what six to eight things would you change or want people to learn and do differently?’ Conversely, a second challenge posed to the authors was slightly more pessimistic: ‘Identify the six to eight mistakes that you regularly see or experience in your area of practise and write about those and how to avoid them’. This approach appeared to stimulate our authors and provided a tangible grounding for their writing – but the real challenge came when we tried to impose an average word limit for each chapter of 3,000 words! In hindsight, the word limit was probably too restrictive for some topics, but it forced authors to be concise and succinct – which we hope you, the reader, appreciate!

Chapters are written as a series of lessons, insights or principles (hereafter referred to only as lessons) that forced authors to be very specific about their key points. Many struggled with this style – but our hope is that it allows you to quickly identify the pertinent information to help you in your day to day tasks. We realised that time is precious – and for most of you – time is money (yours or your bosses!) and we have designed the book so you can quickly and efficiently find the answers to your questions and get back to the planning, designing, building, maintaining or granting approvals to build roads or other transportation infrastructure. And in the likely event that this book does not answer all your questions, the further readings and up-to-date reference lists for each chapter should point you to the extra information you need.

The chapters span the project continuum – starting with planning and design, through construction and into maintenance and management. Research and monitoring is such an important aspect that it sits like an umbrella, encompassing all phases of a transportation project. Rigorous monitoring and evaluation of the impacts of a road or effectiveness of mitigation often requires the collection of data before the road or mitigation is built – hence the chapters on monitoring, evaluation and maintenance come before the impacts and mitigation are described. A significant proportion of the book focuses on impacts and solutions for species groups and specific regions. The rate of major road construction in the United States, Australia and Western Europe has slowed, while developing countries are expanding their road and rail networks at an incredibly rapid rate. This book highlights some of the unique regional challenges with case studies from Asia, South America and Africa.

Chapters are designed to be stand-alone – you do not need to read the book from cover to cover, or even from front to back, to be able to use its contents. We envisage that readers will come to our book when facing a challenge – or rather an opportunity – and they can dive
into the relevant chapter to improve their understanding of the major problems and the array of current possible solutions. Nevertheless, we have endeavoured to ensure that chapters build upon and complement each other – so reading (or even skimming) it from cover to cover won’t be a waste of time. Extensive cross-referencing among chapters directs the reader to relevant material elsewhere in the book.

We should point out what this book is not: it is not a series of standards for the design of roads or mitigation measures. These standards and guidelines already exist in many countries, states or regions and we did not want to repeat them here. If they don’t exist in your region, there are enough around to borrow from in order to develop your own. And because the optimal design and placement of, for example, crossing structures, fences or wildlife detection systems should evolve as our understanding and technology improves, such specific information would be quickly out of date. All the authors in this book have strived to identify the greatest challenges and opportunities and write about them in a way that is timeless.

Our sincere hope is that this book improves the way roads and other linear infrastructure are planned, designed, approved, built, maintained and studied.

Rodney van der Ree
Daniel J. Smith
Clara Grilo
September, 2014
Edited books such as the *Handbook of Road Ecology* are a combined effort of many people – not the least of which are the 115 people from 25 countries that contributed to the 62 chapters. It was a privilege for us to combine your individual expertise into a product that truly exceeded the sum of its parts! Zoe Metherell and Scott Watson generously illustrated numerous figures, and many others assisted in developing the concept, providing figures and editing the final product – including Alan Crowden, Ward Cooper and Kelvin Mathews at Wiley, Radjan LourdeSelvanadin at SPi Global, Lee Harrison, Cindy van der Ree and Marcel Huijser.

Road ecology is most definitely a collaboration between industry and academia, researchers and engineers, government agencies and road construction companies. This handbook is no different. Numerous companies, government agencies, not-for-profit conservation groups and university/research centres have contributed financially to the production and distribution of this book. Funds provided by these generous supporters have allowed us to provide over 200 copies of this handbook to practitioners in developing countries. Further details are available at www.handbookofroadecology.net. We sincerely thank these organisations for their support: ACO Polycrète Pty Ltd, Animex – Animal Exclusion Solutions, the Australian Research Centre for Urban Ecology at the Royal Botanic Gardens Melbourne, Chinese Academy of Transportation Sciences, Eco-Kare International, Florida Wildlife Federation, Melbourne Sustainable Society Institute, School of Ecosystem and Forest Sciences at the University of Melbourne and the Federal Road Office of Switzerland of the Department of Environment, Transport, Energy and Communications.

Rodney: I thank the many ecologists, road practitioners and government regulators who have shared time and experiences discussing, planning, designing and building better roads and other linear infrastructure. I am grateful to Andrew Bennett for guiding me through the perilous days of designing and completing a PhD in what was the nascent days of ‘road ecology’. Mark McDonnell encouraged me to write and edit this volume, and he and the Baker Foundation supported this undertaking. To my co-editors – thanks for bringing complementary skills to the editing table and for sharing the vision of this book! I am particularly appreciative of Cindy’s continuing love and support, who once again allowed me to disappear from family life to complete this project. To Ethan and Ezra – thanks for tolerating my absences and may you forever contemplate the solutions to roadkill and barrier effects as you travel life’s roads.

Dan: I extend a special thank you to four individuals that encouraged, mentored and guided me toward a career in the disciplines of landscape ecology, road ecology and conservation planning – Larry Harris, Gary Evink, Leroy Irwin and Richard Forman. I’d also like to thank Reed Noss for his support and collaboration, which has helped me sharpen my research design and analytical skills and furthered my success as a scientist. My sincere appreciation goes to my co-editors, even though each of us ended up spending many long nights and days on this collaboration, the spirited camaraderie made it an enjoyable learning experience.
Last but not least, thank you to family, friends and colleagues that have inspired me and kept me steadfast towards making a positive difference in the world.

Clara: I thank my parents for their support and enthusiasm for my research and John A. Bissonette for inspiring me to work on road and landscape ecology. Thanks to Rodney for inviting me to participate in this book project. A very special thanks to IENE, ICOET and ICCB conference organisers that allowed me to meet researchers from all parts of the world. Social events at these conferences were priceless to meet most of the authors who contributed to this book, who also share a passion for road ecology as well as the love of good beer and hilarious moments.
ABOUT THE COMPANION WEBSITE

This book is accompanied by a companion website:

www.wiley.com/go/vanderree/roadecology

The website includes:
• Powerpoints of all figures from the book for downloading
• Pdfs of all tables from the book for downloading
THE ECOLOGICAL EFFECTS OF LINEAR INFRASTRUCTURE AND TRAFFIC: CHALLENGES AND OPPORTUNITIES OF RAPID GLOBAL GROWTH

Rodney van der Ree¹, Daniel J. Smith² and Clara Grilo³

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SUMMARY

Roads, railways and utility easements are integral components of human society, allowing for the safe and efficient transport of people and goods. There are few places on earth that are not currently traversed or impacted by the vast networks of linear infrastructure. The ecological impacts of linear infrastructure and vehicles are numerous, diverse and, in most cases, deleterious. Recognition and amelioration of these impacts is becoming widespread around the world, and new roads and other linear infrastructure are increasingly planned to avoid high-quality areas and designed to minimise or mitigate the deleterious effects. Importantly, the negative effects of the existing infrastructure are also being reduced during routine maintenance and upgrade projects, as well as targeted retrofits to fix specific problem areas.
1.1 Global road length, number of vehicles and rate of per capita travel are high and predicted to increase significantly over the next few decades.

1.2 The ‘road-effect zone’ is a useful conceptual framework to quantify the negative ecological and environmental impacts of roads and traffic.

1.3 The effects of roads and traffic on wildlife are numerous, varied and typically deleterious.

1.4 The density and configuration of road networks are important considerations in road planning.

1.5 The costs to society of wildlife-vehicle collisions can be high.

1.6 The strategies of avoidance, minimisation, mitigation and offsetting are increasingly being adopted around the world – but it must be recognised that some impacts are unavoidable and unmitigable.

1.7 Road ecology is an applied science which underpins the quantification and mitigation of road impacts.

The global rates of road construction and private vehicle ownership as well as travel demand will continue to rise for the foreseeable future, including at a rapid rate in many developing countries. The challenge currently facing society is to build a more efficient transportation system that facilitates economic growth and development, reduces environmental impacts and protects biodiversity and ecosystem functions. The legacy of the decisions we make today and the roads and railways we construct tomorrow will be with us for many years to come.

INTRODUCTION

Since ancient times, trails and roads have connected settlements and facilitated the movement of goods and people around the world. The Appian Way (over 500 km long), built in the second and third centuries BC in Italy for military and trade purposes, was one of the first improved (hard-surfaced) highways. Portions of this road still remain today, a testament to the high-quality engineering and construction practices of the Roman Empire and the importance of roads to human society. Up until the early 1900s, the majority of the roads linking cities and towns were mostly unimproved, and paving with brick, concrete or asphalt only became common when mass production of vehicles began and the demand for better quality roads and more efficient routes increased. Depression-era public work programs designed to provide employment opportunities and stimulate economies also facilitated a significant increase in paved roads. Today, road construction is still an important driver of economic growth, both during construction and for its long-term effects. Roads are now conspicuous components of almost all landscapes globally, and set to expand even further into the future (Lesson 1.1).

Transportation infrastructure and roads, in particular, are pivotal to economic and social development by providing access to markets, places of employment, businesses, health and family care, leisure activities and education. Governments and international development banks see the construction of new roads and improvement of existing roads as priorities to improve livelihoods. However, the benefits of improved access vary regionally and by road type (e.g. Fan & Chan-Kang 2005), and not all rural road projects result equally in increased agricultural productivity and/or poverty reduction (Laurance et al. 2014; Chapter 2), and in some cases the costs outweigh the benefits. Once built, roads are nearly permanent elements in the landscape, and the wrong road (e.g. motorway/expressway vs. unpaved road) in the wrong place (e.g. roadless wilderness vs. agricultural landscape) can have long-term consequences for both society and the environment. Planning and impact assessment processes must properly account for all the costs, benefits and environmental impacts to ensure that the future road network is as sustainable as possible, particularly in regions where the rate of road construction is currently high or set to increase (see Chapter 5).

The broad aim of this chapter is to provide the necessary background and context for the many topics covered in this book. While primarily focused on roads and vehicles, the lessons in this chapter and book can be applied to all types of linear infrastructure.