HANDBOOK OF ROAD ECOLOGY
CONTENTS

Notes on contributors, ix

Foreword, xx
RICHARD T. T. FORMAN

Preface, xxi

Acknowledgements, xxiv

About the companion website, xxvi

1 The ecological effects of linear infrastructure and traffic: Challenges and opportunities of rapid global growth, 1
RODNEY VAN DER REE, DANIEL J. SMITH AND CLARA GRILO

2 Bad roads, good roads, 10
WILLIAM F. LAURANCE

3 Why keep areas road-free? The importance of roadless areas, 16
NURIA SELVA, ADAM SWITALSKI, STEFAN KREFT AND PIERRE L. IBISCH

4 Incorporating biodiversity issues into road design: The road agency perspective, 27
KEVIN ROBERTS AND ANDERS SJÖLUND

5 Improving environmental impact assessment and road planning at the landscape scale, 32
JOCHEN A. G. JAEGGER

6 What transportation agencies need in environmental impact assessments and other reports to minimise ecological impacts, 43
JOSIE STOKES

7 Principles underpinning biodiversity offsets and guidance on their use, 51
YUNG EN CHEE

8 Construction of roads and wildlife mitigation measures: Pitfalls and opportunities, 60
CAMERON WELLER

9 Ensuring the completed road project is designed, built and operated as intended, 65
RODNEY VAN DER REE, STEPHEN TONJES AND CAMERON WELLER

10 Good science and experimentation are needed in road ecology, 71
RODNEY VAN DER REE, JOCHEN A. G. JAEGGER, TRINA RYTWINSKI AND EDGAR A. VAN DER GRIFT

11 Field methods to evaluate the impacts of roads on wildlife, 82
DANIEL J. SMITH AND RODNEY VAN DER REE

12 Case study: A robust method to obtain defendable data on wildlife mortality, 96
ÉRIC GUINARD, ROGER PRODON AND CHRISTOPHE BARBRAUD
13 Road–wildlife mitigation planning can be improved by identifying the patterns and processes associated with wildlife-vehicle collisions. 101
KARI GUNSON AND FERNANDA ZIMMERMANN TEIXEIRA

14 Incorporating landscape genetics into road ecology. 110
PAUL SUNNUCKS AND NIKO BALKENHOL

15 Guidelines for evaluating use of wildlife crossing structures. 119
EDGAR A. VAN DER GRIFT AND RODNEY VAN DER REE

16 Guidelines for evaluating the effectiveness of road mitigation measures. 129
EDGAR A. VAN DER GRIFT, RODNEY VAN DER REE AND JOCHEN A. G. JAEGGER

17 How to maintain safe and effective mitigation measures. 138
RODNEY VAN DER REE AND STEPHEN TONJES

18 Understanding and mitigating the negative effects of road lighting on ecosystems. 143
BRADLEY F. BLACKWELL, TRAVIS L. DEVAULT AND THOMAS W. SEAMANS

19 Ecological impacts of road noise and options for mitigation. 151
KIRSTEN M. PARRIS

20 Fencing: A valuable tool for reducing wildlife-vehicle collisions and funnelling fauna to crossing structures. 159
RODNEY VAN DER REE, JEFFREY W. GAGNON AND DANIEL J. SMITH

21 Wildlife crossing structures: An effective strategy to restore or maintain wildlife connectivity across roads. 172
DANIEL J. SMITH, RODNEY VAN DER REE AND CARME ROSELL

22 Recreational co–use of wildlife crossing structures. 184
RODNEY VAN DER REE AND EDGAR A. VAN DER GRIFT

23 Predator–prey interactions at wildlife crossing structures: Between myth and reality. 190
CRISTINA MATA, ROBERTA BENCINI, BRIAN K. CHAMBERS AND JUAN E. MALO

24 Wildlife warning signs and animal detection systems aimed at reducing wildlife-vehicle collisions. 198
MARCEL P. HUIJSER, CHRISTA MOSLER-BERGER, MATTIAS OLSSON AND MARTIN STREIN

25 Use of reflectors and auditory deterrents to prevent wildlife-vehicle collisions. 213
GINO D’ANGELO AND RODNEY VAN DER REE

26 Ecological effects of railways on wildlife. 219
BENJAMIN DORSEY, MATTIAS OLSSON AND LISA J. REW

27 Impacts of utility and other industrial linear corridors on wildlife. 228
A. DAVID M. LATHAM AND STAN BOUTIN

28 The impacts of roads and traffic on terrestrial animal populations. 237
TRINA RYTWINSKY AND LENORE FAHRIG

29 Insects, snails and spiders: The role of invertebrates in road ecology. 247
HEINRICH RECK AND RODNEY VAN DER REE

30 Case study: Protecting Christmas Island’s iconic red crabs from vehicles. 258
ROB MULLER AND MIKE MISSO

31 Making a safe leap forward: Mitigating road impacts on amphibians. 261
ANDREW J. HAMER, THOMAS E. S. LANGTON AND DAVID LESBARRÈRES

32 Reptiles: Overlooked but often at risk from roads. 271
KIMBERLY M. ANDREWS, TOM A. LANGEN AND RICHARD P. J. H. STRUIJK

33 Flight doesn’t solve everything: Mitigation of road impacts on birds. 281
ANGELA KOCIOLEK, CLARA GRILIO AND SANDRA JACOBSON

34 Bats and roads. 290
ISOBEL M. ABBOTT, ANNA BERTHINUSSEN, EMMA STONE, MARTIJN BOONMAN, MARKUS MELBER AND JOHN ALTRINGHAM

35 Carnivores: Struggling for survival in roaded landscapes. 300
CLARA GRILIO, DANIEL J. SMITH AND NINA KLAAR
36 Case study: Roads and jaguars in the Mayan forests, 313
   EUGENIA PALLARES, CARLOS MANTEROLA, DALIA A. CONDE AND FERNANDO COLCHERO

37 Case study: Finding the middle road – grounded approaches to mitigate highway impacts in tiger reserves, 317
   SANJAY GUBBI AND H.C. POORNESA

38 Case study: African wild dogs and the fragmentation menace, 322
   BRENDAN WHITTINGTON-JONES AND HARRIE T DAVIES-MOSTERT

39 Roads, traffic and verges: Big problems and big opportunities for small mammals, 325
   FERNANDO ASCENSÃO, SCOTT LAPOINT AND RODNEY VAN DER REE

40 Reducing road impacts on tree-dwelling animals, 334
   KYLIE SOANES AND RODNEY VAN DER REE

41 Case study: Canopy bridges for primate conservation, 341
   ANDREA DONALDSON AND PAMELA CUNNEYWORTH

42 Transportation and large herbivores, 344
   PATRICIA CRAMER, MATTIA S OLSSON, MICHELLE E. GADD, RODNEY VAN DER REE AND LEONARD E. SIELECKI

43 Case study: The Mount Kenya elephant corridor and underpass, 353
   SUSIE WEEKS

44 Form and function: A more natural approach to infrastructure, fish and stream habitats, 357
   PAUL J. WAGNER

45 Solutions to the impacts of roads and other barriers on fish and fish habitat, 364
   FABRICE OTTBURG AND MATT BLANK

46 The function and management of roadside vegetation, 373
   SUZANNE J. MILTON, W. RICHARD J. DEAN, LEONARD E. SIELECKI AND RODNEY VAN DER REE

47 Roads in the arid lands: Issues, challenges and potential solutions, 382
   ENHUA LEE, DAVID B. CROFT AND TAMAR ACHIRON-FRUMKIN

48 Road ecology in an urbanising world, 391
   DARRYL JONES, HANS BEKKER AND RODNEY VAN DER REE

49 Tropical ecosystem vulnerability and climatic conditions: Particular challenges for road planning, construction and maintenance, 397
   MIRIAM GOOSEM

50 The influence of economics, politics and environment on road ecology in South America, 407
   ALEX BAGER, CARLOS E. BORGHI AND HELIO SECCO

51 Highway construction as a force in the destruction of the Amazon forest, 414
   PHILIP M. FEARNSIDE

52 Road ecology in South India: Issues and mitigation opportunities, 425
   K. S. SESHADRI AND T. GANESH

53 Planning roads through sensitive Asian landscapes: Regulatory issues, ecological implications and challenges for decision-making, 430
   ASHA RAJVANSHI AND VINOD B. MATHUR

54 Setjhaba SA, South Afrika: A South African perspective of an emerging transport infrastructure, 439
   WENDY COLLINSON, DAN PARKER, CLAIRE PATTERSON-ABROLAT, GRAHAM ALEXANDER AND HARRIET DAVIES-MOSTERT

55 Unfenced reserves, unparalleled biodiversity and a rapidly changing landscape: Roadways and wildlife in East Africa, 448
   CLINTON W. EPPS, KATARZYNA NOWAK AND BENEZETH MUTAYOBA

56 Expected effects of a road across the Serengeti, 455
   MICH ELL E. GADD
57 China: Building and managing a massive road and rail network and protecting our rich biodiversity. 465
  YUN WANG, YAPING KONG AND JIDING CHEN

58 Railways, roads and fences across Kazakhstan and Mongolia threaten the survival of wide-ranging wildlife. 472
  KIRK A. OLSON AND RODNEY VAN DER REE

59 Best-practice guidelines and manuals. 479
  MARGUERITE TROCMÉ

60 Case study: The role of non-governmental organisations (NGOs) and advocates in reducing the impacts of roads on wildlife, 485
  PATRICIA WHITE

61 Case study: Building a community of practice for road ecology. 488
  PAUL J. WAGNER AND ANDREAS SEILER

62 Wildlife/roadkill observation and reporting systems, 492
  FRASER SHILLING, SARAH E. PERKINS AND WENDY COLLINSON

Glossary. 502
Species. 509
Index. 513
NOTES ON CONTRIBUTORS

Dr Isobel M. Abbott completed her PhD in 2012 on the effects of major roads on bats, at University College Cork, Ireland. She works as a freelance ecologist with broad interests in nature conservation and research, specialising in bat ecology. Recent projects include ecological impact assessments of roads and windfarms on bats.

Dr Tamar Achiron-Frumkin (DPhil, Oxford) is an ecologist and environmental advisor. Since the early 2000s, she has worked on various biodiversity conservation projects, gradually focusing on habitat connectivity and traffic-related issues. She was involved in the design of a few ecoducts and in monitoring usage. She produced a local version of COST 341, and initiated a project investigating the use and prioritization of existing road structures as animal passages to minimise fragmentation for the Israel National Transportation Infrastructure Company.

Graham Alexander is a professor at the University of the Witwatersrand, South Africa, where he heads a research laboratory that focuses on ecology, physiology, biogeography, and conservation of reptiles. He has a particular interest in elucidating causality of range limitation in reptiles, and using this information for conservation purposes.

John Altringham is Professor of Animal Ecology and Conservation at the University of Leeds in the UK. He has published three books on bats and numerous scientific papers and popular articles, many of them on bats and bat conservation. He works with a wide variety of conservation organisations.

Dr Kimberly M. Andrews has a joint position between Jekyll Island State Park Authority and University of Georgia (UGA) Savannah River Ecology Laboratory and is graduate faculty at the UGA Odum School of Ecology. Her lab focuses on small vertebrates and conducts field research on wildlife spatial ecology, land-use effects on habitat quality, and wildlife-human interactions. These field data serve as the basis for habitat management, land-use planning and infrastructure development, conflict resolution, and public education practices.

Fernando Ascensão holds a PhD in conservation biology. He studies animal-road interactions, including its effects on animal movement, landscape connectivity, gene flow, and population persistence. He undertakes his research in Portugal and Brazil, where he is currently a postdoc fellow in Brazilian Road Ecology Research Group (Lavras University). His goal is contributing to the development of sustainable transportation networks worldwide.

Alex Bager is the Coordinator of the Brazilian Road Ecology Centre (CBEE), and Professor at the Universidade Federal de Lavras, Brazil. Since 1995, he has been working on animal–vehicle collisions and barrier effects of roads. He is also coordinator of Urubu (Vulture) System, a social networking application to reduce the environmental impacts of roads and railroads on biodiversity.

Niko Balkenhol is Professor of Wildlife Management at the Faculty of Forestry and Forest Ecology of the University of Göttingen, Germany. His teaching and research focus on spatial and molecular approaches for wildlife ecology, conservation and management.
Christophe Barbraud is a researcher at Centre d’Études Biologiques de Chizé (CEBC) – Centre National de la Recherche Scientifique (CNRS) since 2001. He is mainly interested in modelling population dynamics of vertebrates in relation to climate variability. He uses long-term individual monitoring data (demography, biometrics, ecology at sea) of birds and marine mammals.

Hans Bekker was an eco-engineer with Rijkswaterstaat of the Dutch Ministry of Transport, Public Works and Water Management. He was a program leader with environmental issues, mainly wildlife, roads/rails and traffic, and acted as a bridge between civil engineers and ecologists, policy and projects, scientists and practitioners. Hans co-initiated the Infra Eco Network Europe (IENE), in 1995, was a member of steering committee of ICOET (USA), chaired COST 341 and ran the Dutch Long-Term De-fragmentation Program. Hans retired in 2015.

Dr Roberta Bencini is an associate professor in the Wildlife Research Group, School of Animal Biology, at the University of Western Australia. Since 2005, she has been investigating methods to mitigate the negative effects of roads and other developments on wildlife, including underpasses and rope bridges.

Dr Anna Berthinussen completed her PhD in 2013 on the effects of roads on bats and the effectiveness of current mitigation practice, at the University of Leeds, UK. She is currently working on a Defra-funded study of the interactions between bats and roads, and has plans to continue her career in research and wildlife conservation.

Bradley F. Blackwell, PhD, serves as a research wildlife biologist for the NWRC. His research focuses on exploiting animal sensory ecology and antipredator behavior in the development of technology, for example vehicle lighting systems, and habitat-management guidelines, to reduce animal–vehicle collisions, particularly wildlife–aircraft collisions.

Matt Blank, PhD, is an assistant research professor at the Western Transportation Institute and the Department of Civil Engineering at Montana State University. As part of the Road Ecology program at WTI, Dr Blank performs research focused on fish passage, fish swimming abilities, dam removal and river hydraulics. He has over 20 years of experience in the academic and practical engineering world. He also teaches applied fluid mechanics at MSU, and does water resource consulting with Environmental Resources Management (ERM).

Martijn Boonman is a consultant at Bureau Waardenburg, the Netherlands. He is involved in projects considering monitoring, environmental impact assessments (EIA), ecological infrastructure and the effectiveness of fauna crossings under motorways. An important part of the EIAs consists of studies on bats in windfarms.

Dr Carlos E. Borghi is the Director of the Centro de Investigaciones de la Geósfera y la Bósfera (CIGEOBIO) – Universidad Nacional de San Juan and Consejo Nacional de Investigaciones Científicas y Técnicas (Argentina). His research focuses on animal ecology and animal–plant interaction in deserts and the effect of human perturbations on wildlife.

Stan Boutin is a professor in the Department of Biological Sciences, University of Alberta, and Alberta Biodiversity Conservation Chair. His research interests include forestry–wildlife interactions, cumulative effects, integrated landscape management and population dynamics of boreal vertebrates.

Dr Brian K. Chambers is an assistant professor in the Wildlife Research Group, School of Animal Biology, at the University of Western Australia. The focus of his research revolves around the issue of urbanisation and its impact on native Australian mammals and reptiles through habitat modification, fragmentation and the construction of linear infrastructure such as roads.

Dr Yung En Chee is a quantitative ecologist at The University of Melbourne with research experience in statistical, spatial and ecological modelling. Often working in multi- and interdisciplinary teams, her research focuses on applying ecological and decision analysis theory, models and methods to provide data-driven, practical decision support for conservation and ecosystem management problems. She has authored a reference resource of tools designed to guide and enhance the rigour of Strategic Environmental Assessments (Chee et al. 2011, http://www.academia.edu/3412596/Methodologies_and_Tools_for_Strategic_Assessments_under_the_EPBC_Act_1999).

Professor Jiding Chen received his MSc degree in ecology from Peking University in 1992 and since then works for China Academy of Transportation Sciences (CATS). Now he is the vice president of CATS. His research area includes road ecology, green transportation, scenic byway planning and management, and environmental impact assessment.
Fernando Colchero is an assistant professor in the Department of Mathematics and Computer Science and in the Max-Planck Odense Center for the Biodemography of Aging, University of Southern Denmark. He is a member of the Scientific Board of Jaguar Conservancy, A.C. He is an ecologist by training, and his work focuses on developing statistical methods to understand demographic and spatial dynamics of wild animal populations.

Wendy Collinson is the project executant of the Endangered Wildlife Trust’s Wildlife and Roads Project. She has an MSc (Rhodes University, South Africa), which examined the impacts of roads on South African wildlife. She is currently driving initiatives that address the now-recognised threat of roads in South Africa. In addition, she is creating a national network to raise awareness and further quantify road ecology issues through proactive mitigation measures such as a Roadkill Sensitivity Map and best practice guidelines for road development.

Dalia A. Conde is an Assistant Professor in the Institute of Biology and in the Max-Planck Odense Center for the Biodemography of Aging, University of Southern Denmark. She is a member of the Scientific Board of Jaguar Conservancy, A.C. She did her PhD in ecology at the Nicholas School of the Environment, Duke University. Her dissertation focused on the impact of roads on biodiversity.

Patricia Cramer is a research assistant professor at Utah State University in the United States, and an independent wildlife researcher. An expert on wildlife, roads and crossing structures, she works with Departments of Transportation and Wildlife Agencies to research wildlife near roads in Utah, Montana, Idaho, Oregon, Washington and other states. She received the Denver Zoo’s 2010 Conservationist of the Year award, and the 2013 US Federal Highways Environmental Excellence Award in Research for her work in Utah.

Dr David B. Croft is a visiting fellow in the School of Biological, Earth and Environmental Sciences at UNSW. With a PhD from the University of Cambridge, David taught vertebrate biology, animal behaviour and ecology, and natural resource management in the arid lands. He has published research on invertebrates, marsupials, sheep, marine mammals and primates. His specialty is the behavioural ecology of kangaroos with a recent focus on interactions with people in livestock enterprises, on roads and in wildlife tourism.

Pamela Cunneyworth is a Director of Colobus Conservation overseeing the primate research and conservation activities of the organisation. She has worked in Africa since 1992 in advocacy related to the international conventions of biodiversity and desertification as well as in testing and implementing solutions addressing primate and forest conservation issues. Currently, she is working to develop best practice guidelines for human–primate conflicts for south-east Kenya.

Gino D’Angelo is the Deer Research Project Leader for the Farmland Wildlife Populations and Research Group of Minnesota Department of Natural Resources in Madelia, MN, USA. Gino’s research has focused on the evaluation and development of strategies to minimize deer–vehicle collisions, physiological capabilities of white-tailed deer, deer movement ecology, and management of wildlife damage.

Dr Harriet Davies-Mostert is Head of Conservation at the Endangered Wildlife Trust, one of South Africa’s largest conservation NGOs. She provides strategic scientific oversight to conservation projects across southern Africa, promoting practical evidence-based research as the basis for effective strategies to conserve southern Africa’s rich biodiversity heritage. President of the South African Wildlife Management Association, Harriet is also a member of the Cat, Canid and Conservation Breeding specialist groups of the IUCN’s Species Survival Commission.

Dr W. Richard J. Dean is an ornithologist and research associate of the Percy FitzPatrick Institute for African Ornithology, University of Cape Town. After retiring from academia, he started an indigenous nursery and ecological consulting and restoration business in the arid Karoo region of South Africa with Sue Milton. See http://www.renu-karoo.co.za.

Travis L. DeVault, PhD, serves as a Research Wildlife Biologist and Project Leader for the NWRC. His research centres on wildlife ecology and behaviour, with an emphasis on resolution of human–wildlife conflicts. He is particularly interested in how land-use practices on and near airports can be modified to reduce wildlife–aircraft collisions, while increasing revenue potential and renewable energy production for airports.

Andrea Donaldson is the Conservation Manager at the Kenyan based Colobus Conservation and a PhD student affiliated to Durham University in the United Kingdom. She co-ordinates interdisciplinary research
and monitoring projects relating to primate and forest conservation, including human-primate conflicts.

Benjamin Dorsey is a research assistant at Montana State University, where he also obtained his MSc on wildlife mortality along the Canadian Pacific Railway. He has also worked for several years on the Trans-Canada Highway Wildlife Crossings project. When not working he enjoys travelling the world by rail, and rock climbing.

Clinton W. Epps studies connectivity, gene flow, animal movement and wildlife conservation in Tanzania, southern Africa and the United States. He is an associate professor in the Department of Fisheries and Wildlife at Oregon State University. He is interested in documenting, modelling and conserving connectivity of animal populations in fragmented landscapes.

Lenore Fahrig is professor of biology at Carleton University, Ottawa, Canada. The overall goal of her research is to understand how landscape structure – for example spatial patterning of roads, forestry and agricultural regions – affects the abundance, distribution and persistence of organisms. A particular focus is on the effects of roads and traffic on wildlife populations, using a combination of spatial simulation modelling and field studies. She is currently a board member of the Ontario Road Ecology Group.

Philip M. Fearnside is a research professor at Brazil’s National Institute for Research in Amazonia (INPA) in Manaus. He lived with settlers on Brazil’s Transamazon Highway (BR-230) for 2 years and has also studied the BR-364, BR-163 and BR-319 Highways. He has over 500 publications on developments such as roads and their impacts (see http://philip.inpa.gov.br). Recipient of numerous awards, in 2006 Thompson ISI identified him as the world’s second most highly cited scientist in the area of global warming.

Michelle E. Gadd works at the US Fish and Wildlife Service where she oversees the African elephant and African rhino conservation programs. Her research interests include conservation outside of parks and the effects of barriers on African mammals.

Jeffrey W. Gagnon has worked for AZGFD since 1997, currently as a statewide, research biologist, focusing for the past decade on wildlife–highway interactions throughout Arizona, including State Route 260 and US Highway 93 wildlife crossing projects. Jeff works closely with Arizona Department of Transportation on numerous projects to ensure wildlife concerns are properly addressed. Jeff received his MS from Northern Arizona University where he studied the effects of traffic volumes on elk movements associated with highways and wildlife underpasses.

Dr T. Ganesh is a senior fellow at ATREE. For over three decades, he has worked and advised students on various ecological aspects primarily focussing on plant–animal interaction; bird and primate ecology; ecological restoration and long-term monitoring of forests. He was pivotal in establishing nature clubs and conducting outreach activities in various schools in Western Ghats and also authored a bilingual multi-taxa field guide. He is an avid bird watcher and enjoys travelling to natural landscapes.

Miriam Goosem is Principal Research Fellow in the Centre for Tropical Environmental Sustainability Science at James Cook University, Cairns, Australia. Her research in the field of rainforest road ecology spans 25 years including a variety of vegetation and wildlife fragmentation impacts. She was involved, together with colleagues, in the implementation in rainforest of the first purpose-built underpasses and rope canopy bridges between 1995 and 2005 and continues to monitor their effectiveness.

Clara Grilo is a postdoctoral researcher of the Department of Biology and CESAM, at the University of Aveiro, Portugal. Her primary interest is applied ecological research in support of active conservation projects. Currently, much of her research is focused on the impact of anthropogenic changes to the landscape and effects on wildlife.

Sanjay Gubbi is a wildlife biologist who works on understanding tigers, leopards and their interactions with development and other aspects. He is currently leading research on leopard distribution, density estimation and understanding leopard–human conflict in protected areas, multiple use forests and human dominated landscapes. He is keenly interested in applied conservation activities that have resulted in various on-ground conservation successes in the Western Ghats, southern India. He works with the government to reduce impacts of roads in ecologically sensitive areas.

Éric Guinard is a civil engineer, doctor in Ecology in the Centre d’Études et d’expertise sur les Risques, l’Environnement, la Mobilité et l’Aménagement – Direction Territoriale du Sud-Ouest (CEREMA–DTerSO)
near Bordeaux since 2005. He is in charge of expertise and management assistance of ecological studies on road and motorway projects. He also participates in the development of methods and conducts applied research projects, mainly concerning interactions between transportation infrastructure or urban extension and natural habitats.

Kari Gunson has worked for 15 years informing road–wildlife mitigation projects throughout North America. She lives in Ontario, Canada, and works for Eco-Kare International, translating road ecology science into practical mitigation solutions. She has provided expertise for design, placement and monitoring of mitigation measures for a variety of animals. Her work has contributed to 14 peer-reviewed published articles in the fields of road ecology and geographic information science.

Dr Andrew J. Hamer is an ecologist at the Australian Research Centre for Urban Ecology, a division of the Royal Botanic Gardens Melbourne and located at the University of Melbourne. His research is directed towards understanding the drivers underpinning how amphibians and freshwater turtles respond to urbanisation. He is currently involved in a research project investigating the behaviour of Australian frogs at under-road tunnels. He is also researching broad-scale trends in amphibian and turtle populations in the face of increasing urbanisation.

PD Dr-Ing. Heinrich Reck studied agricultural biology and landscape conservation at Hohenheim and Stuttgart Universities and obtained his post-doctoral lecturing qualification (Habilitation) in landscape ecology at Kiel University. He works as a senior researcher and lecturer on the interface between spatial environmental planning and animal ecology and is a member of the state planning council of Schleswig-Holstein, Germany. He has worked on road ecology and application-oriented research on impact mitigation and compensation work since 1990.

Marcel P. Huijser received his MS in population ecology (1992) and his PhD in road ecology (2000) at Wageningen University, the Netherlands. He studied plant–herbivore interactions in wetlands (1992–1995), hedgehog traffic victims and mitigation strategies (1995–1999), and multifunctional land use issues (1999–2002) in the Netherlands. Marcel has been conducting road ecology research for the Western Transportation Institute at Montana State University (USA) since 2002, and he is currently a visiting professor at the University of São Paulo, Brazil (ESALQ, Piracicaba campus).

Pierre L. Ibisch, Professor for Nature Conservation with Eberswalde University for Sustainable Development, Germany. He holds a research professorship on ‘Biodiversity and natural resource management under global change’ and is Co-director of the Centre for Econics and Ecosystem Management. He has special interests in adaptation to global change and integration of risk management in adaptive biodiversity conservation management, functionality of ecosystems and conservation priority setting, spatial planning, and protected area management.

Sandra Jacobson is a wildlife biologist for USDA Forest Service, Pacific Southwest Research Station specializing in transportation ecology. She designs mitigation for highway impacts to species ranging from elephants to butterflies internationally. Her projects and graduates have received numerous awards, including from the USA FHWA. She is a Steering Committee member of ICOET, a charter member of the Transportation Research Board’s Committee on Ecology and Transportation and a Steering Committee member of the ARC Design Forum for wildlife crossing structures.

Jochen A. G. Jaeger is an associate professor in the Department of Geography, Planning and Environment at Concordia University in Montreal, Canada. He received his PhD in Environmental Sciences from the Swiss Federal Institute of Technology (ETH) in Zurich in 2000. His research is in the fields of landscape ecology with a focus on landscape fragmentation and urban sprawl, road ecology, ecological modelling, environmental indicators, environmental impact assessment and novel concepts of problem-oriented trans-disciplinary research.

Darryl Jones is an Professor at Griffith University, in Brisbane, Australia, and Deputy Director of the Environmental Futures Research Institute at that university. He has been actively engaged in urban ecology since the early 1980s and in road ecology research for over 10 years.

Dr Nina Klar is working at the federal administration of Hamburg, Germany, being responsible for native species conservation. She is especially interested in wildlife species living in human-dominated landscapes. After her research on wildcats and road ecology, she is now conducting conservation projects for urban wildlife.
Angela Kociolek is a Research Scientist at the Western Transportation Institute, Montana State University-Bozeman, Bozeman, USA, where she conducts road ecology research and outreach to transportation professionals. Angela is currently the Technology Transfer Initiative Leader for ARC, a partnership seeking to make wildlife crossing structures a standard practice across North America.

Yaping Kong is a Professor who received her MS degree in ecology from Beijing Normal University in 2002, and since then has worked for the China Academy of Transportation Sciences (CATS). Now she is the vice-director of the Research Centre for Environmental Protection and Transportation Safety. Her research area includes vegetation restoration, water resource protection, road geological disaster control, ecological highway planning and management, transportation policy making, EIA and road ecology.

Stefan Kreft is a researcher with the Centre for Econics and Ecosystem Management, Eberswalde University for Sustainable Development, Germany. Under the impression of rapid land-use changes in South America, his research priorities have gradually shifted away from species conservation to ecosystem-based conservation approaches, addressing adaptation to climate change in particular. Besides a current focus on Europe, developing and transitional countries remain of great interest to him. He is member of the Roadless Areas Initiative of the Society for Conservation Biology.

Dr Tom A. Langen is Professor of biology, Clarkson University. He conducts road-related environmental research including winter road management, predictive modelling of road mortality hotspots, design of wildlife barriers and passageways for turtles, and the impact of highways on habitat connectivity in Costa Rican National Parks. He leads workshops in Latin America and North America on the environmental impact of roads and other infrastructure.

Dr Enhua Lee is a senior ecologist at the environmental consulting company, Eco Logical Australia. She has prepared numerous biodiversity strategies, biodiversity and natural resource management plans, and environmental impact assessments. Enhua conducted her PhD at UNSW on the ecological impacts of roads in arid ecosystems, investigating impacts on soil, vegetation, kangaroo, small mammal and lizard distributions and abundance, and kangaroo behaviour and mortality.

A. David M. Latham is a wildlife ecologist with Landcare Research, New Zealand. His research interests include vertebrate pest research; predator–prey ecology; spatial ecology; large mammal ecology, conservation and management; and human disturbance–wildlife interactions.

William F. Laurance is a distinguished research professor and Australian Laureate at James Cook University in Cairns, Australia, and also holds the Prince Bernhard Chair in International Nature Conservation at Utrecht University, the Netherlands. He studies the ecology and conservation of tropical forests throughout the world, and to date has authored seven books and over 400 scientific and popular articles. He is a fellow of the American Association for the Advancement of Science and former president of the Association for Tropical Biology and Conservation. He is also director of the Centre for Tropical Environmental and Sustainability Science at James Cook University as well as founder and director of the leading international scientific organisation ALERT—the Alliance of Leading Environmental Researchers and Thinkers.

Dr David Lesbarrères is an associate professor at the Centre for Evolutionary Ecology and Ethical Conservation, Laurentian University in Sudbury, Canada. His main interests are focused on theoretical and applied questions about the evolution and ecology of amphibian species and communities. His research program is currently centred on population genetics in human dominated landscapes, road ecology and emerging infectious diseases,
ultimately integrating all these aspects to understand the declines of amphibian populations.

Dr Juan E. Malo is an associate professor and researcher at the Terrestrial Ecology Group of Universidad Autónoma de Madrid. His research interests include ecological interactions and the effects of human activities on wildlife populations, with a special focus to environmental impact assessment of infrastructures and fragmentation.

Carlos Manterola is the General Director of Grupo Anima Efferus A.C. and the Director of Conservation of Jaguar Conservancy, A.C., in Mexico. He was General Director of the conservation NGO Unidos para la Conservación. He has led numerous conservation projects including the establishment of Protected Areas in Mexico, the protection and recovery of the pronghorn antelope in Mexico, management of desert bighorn sheep on Tiburon Island and the conservation of jaguars and their habitat in Mexico and Central America.

Dr Cristina Mata is a postdoctoral researcher at the Terrestrial Ecology Group of Universidad Autónoma de Madrid (Spain). Her main research is focused on monitoring and assessment of mitigation measures aimed at the reduction of habitat fragmentation by roads and railways.

Dr Vinod B. Mathur is the Director, Wildlife Institute of India. He obtained his doctoral degree in wildlife ecology from the University of Oxford in 1991. He is Regional Vice-Chair of the IUCN-World Commission on Protected Areas (WCPA-South Asia). He is a member of UN-IPBES Multidisciplinary Expert Panel (MEP). His areas of interest are Impact Assessment and Road Ecology.

Dr Markus Melber studies the impact of roads on bats as well as the effectiveness of mitigation projects for bats along a heavy-traffic motorway but also the ecology of forest-living bats. Besides working as a research associate at the University of Greifswald, Germany, he has also worked for several German federal agencies. He often acts as an advisor for public agencies on mitigation projects and on conservational topics. His work has resulted in several scientific publications, book chapters and reports.

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 wildlife crossing.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.
Foreword

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-rippling 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 pre-cient 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 LourdesSelvanadin 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 Polycrrete 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
Chapter 1

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

¹Australian Research Centre for Urban Ecology, Royal Botanic Gardens Melbourne, and School of BioSciences, The University of Melbourne, Melbourne, Victoria, Australia
²Department of Biology, University of Central Florida, Orlando, FL, USA
³Departamento de Biologia & CESAM, Universidade de Aveiro, Aveiro, Portugal

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.