

Invading Nature - Springer Series in Invasion Ecology

Volume 12

Series Editor

Daniel Simberloff
Ecology and Evolutionary Biology
Knoxville
Tennessee
USA

Biological Invasions represent one of those rare themes that cut across the disciplines of academic biology, while having profound environmental, philosophical, socioeconomic, and legislative implications at a global scale. There can be no doubt that biological invasions represent the single greatest threat to biodiversity past the activities of humankind itself. The implications are far reaching. Novel ecological and evolutionary forces are now directing the future expression of life itself, as native species and the communities that they comprise contend with invading species. The rules of the game have been suddenly and irrevocably changed.

Invading Nature - Springer Series in Invasion Ecology is a new book series topically spanning the breadth of invasion biology. The series is of singular importance as an integrative venue focusing on the broader ecological and evolutionary issues arising from non-native species, the impacts such species have in particular environments, trends patterns and processes, as well as causes and correctives. The series seeks novel and synthetic approaches to invasions including experimental, theoretical, systematic and conceptual treatments

Prospective authors and/or editors should consult the **Series Editor Daniel Simberloff** for more details:

e-mail: tebo@utk.edu

More information about this series at <http://www.springer.com/series/7228>

Montserrat Vilà • Philip E. Hulme
Editors

Impact of Biological Invasions on Ecosystem Services



Editors

Montserrat Vilà
Doñana Biological Station (EBD-CSIC)
Sevilla, Spain

Philip E. Hulme
The Bio-Protection Research Centre
Lincoln University
Lincoln, Canterbury, New Zealand

Invading Nature - Springer Series in Invasion Ecology

ISBN 978-3-319-45119-0

ISBN 978-3-319-45121-3 (eBook)

DOI 10.1007/978-3-319-45121-3

Library of Congress Control Number: 2017931686

© Springer International Publishing Switzerland 2017

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by Springer Nature

The registered company is Springer International Publishing AG

The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To our families who give us the time to learn

Foreword by Braulio Ferreira de Souza Dias

Invasive alien species are considered a direct driver of biodiversity loss, a key issue affecting all major biomes. Invasive alien species are also known to cost our economies billions of dollars each year. The cost arises from economic loss in the agriculture, forestry, energy, and health sectors, negative effects on the delivery of ecosystem services, and the price tag for control and eradication efforts once invasive alien species are established.

Article 8h of the Convention of Biological Diversity (CBD) states that “*Each contracting Party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species*” to address the issue of invasive alien species. In 2002 the CBD Parties adopted the guidelines for the prevention, eradication, and control of invasive alien species, and at the tenth meeting of the Conference of the Parties (COP) to the CBD, held in Nagoya, Aichi Prefecture, Japan in 2010, the Parties adopted the Strategic Plan for Biodiversity 2011-2020 and its 20 Aichi Biodiversity Targets, including Target 9: “*By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated and measures are in place to manage pathways to prevent their introduction and establishment.*” Furthermore, in 2015 the United Nations General Assembly adopted the 2030 Sustainable Development Agenda, and agreed for target 15.8 on invasive alien species to be achieved by 2020, the same year as targeted for the Aichi Biodiversity Target 9. These global objectives reinforce the urgency of appropriate invasive alien species management as a contribution to sustainable development.

To achieve these targets, the CBD, through its Subsidiary Body of Scientific, Technical and Technological Advice (SBSTTA) and the COP, has continued to develop international guidance and possible response measures. As a result, many countries have advanced in developing strategies and putting measures in place to prevent invasions and minimize the negative impacts of invasive alien species. Nonetheless, the fourth edition of *Global Biodiversity Outlook (GBO-4)* warns that even though there has been significant progress toward meeting some Aichi targets, the overall rate of invasions has shown no sign of slowing down.

The increase in international trade, travel, and related modern technology intensifies the risk of entry and spread of alien species that become invasive in many different biogeographic regions across the world. If we do not take prompt action, the known and potential impacts of invasive alien species on biodiversity and ecosystem services can cast a shadow on the sustainable development agenda. A key approach is the analysis of scientific evidence of high-impact invasive species and the analysis of introduction pathways as a means to prioritize these and to apply effective preventive or control measures.

To that end, information on the impacts caused by invasive alien species on biodiversity, ecosystem services, and functions is essential for assessing risks from biological invasion to both economy and environment. The publication of *Impact of Biological Invasions on Ecosystem Services* comes at a critical time when countries seek to accelerate actions to achieve the Aichi Biodiversity Targets. It enhances awareness about the impacts of invasive alien species on biodiversity and related issues such as food and water security, climate adaptation and mitigation, or the sustainable supply of biological materials, among others. With continuous monitoring and sharing of information regarding the global impacts of invasive alien species on biodiversity and ecosystem services, countries will be in a better position to prevent biological invasions and thereby achieve related sustainable development ambitions.

I would like to encourage experts, land, water, and resource managers, and control officers to widely use the knowledge compiled in this publication for the sustainable management of ecosystems, and thus ensure that our biodiversity can continue to generate its invaluable and irreplaceable benefits for future generations.

Convention on Biological Diversity
Montreal, QC, Canada

Bráulio Ferreira de Souza Dias

Foreword by Piero Genovesi

The current dramatic extinction crisis and the increasing pace of loss of biodiversity require urgent action by the global community, whose efforts have so far proven to be inadequate. Addressing the global threats to biodiversity is essential not only for preserving wild species and ecosystems but also for protecting our livelihood, which largely depends on healthy natural systems.

Biological invasions are indeed one of the major drivers of change at the global scale, and one for which action has been so far particularly sparse. To guide policy, it is therefore essential to better understand the effects of the increasing introduction of invasive species: important not only in terms of biodiversity loss but also with regard to effects these invasions have on our lives. Indeed, this is a primary concern for decision makers, particularly in developing areas of the world.

This book, authored by an impressive group of leading experts on the impacts of non-native species, presents the first comprehensive overview of how non-native species alter the services to humans provided by natural ecosystems and includes an in-depth analysis of the patterns and trends of these impacts. The volume provides a much-needed up-to-date picture of the severe effects of non-native species on the quality and quantity of products obtained from ecosystems, such as crops, timber, and fish stocks. It also explores the effects of biological invasions on the regulation of ecosystems, as in the case of disruptive effects of non-native species on water regulation, describing the impact on erosion, water quality, and other key services associated with freshwater. The book also discusses the impacts of biological invasions on health, analysing the effects of the expansion of non-native mosquitoes and of the consequent spread of many diseases, for example. Last but not least, this book addresses the impacts of invasions on the cultural services provided by ecosystems, analysing the effects on recreational and aesthetic values.

This volume, structured in four sections, not only analyses the known impacts of nonnative species on all ecosystem services but also includes a synthesis of the main results that is particularly valuable for defining the information gaps on this aspect and, eventually, for informing decision makers.

The merit of this excellent text is to present the first-ever analysis of the impacts of biological invasions on ecosystem services, with scientific rigour, but also in a

form that can be understood by different audiences, from scientists to students to practitioners and decision makers. This information is the key to informing the entire society on the need and importance of addressing biological invasions, showing that protecting nature from this threat also preserves our life.

Institute for Environmental
Protection and Research
IUCN SSC Invasive Species Specialist Group
Rome, Italy

Piero Genovesi

Foreword by Helen E. Roy

Biological invasions are widely considered as a major threat to biodiversity and ecosystem function. However, there is a need to improve the understanding of impacts of biological invasions and to provide robust empirical evidence to underpin decision making. There is an increasing need to consider the impacts of an alien species at various scales, recognizing the complexity of interactions within communities and ecosystems. Indeed, the importance of impacts of alien species on ecosystem function and consequently ecosystem services has been highlighted within the new EU Regulation on Invasive Alien Species. A number of studies have demonstrated the challenges of quantifying impacts on ecosystem services, not least the need for a consolidated framework in which to define the types of ecosystem services. Therefore, this book represents a timely contribution, providing a synthesis of research to advance understanding of impacts of alien species.

It is exciting to see the range of topics covered within this book and spanning the defined ecosystem services: supporting, provisioning, regulating, and cultural. From changes in primary production to carbon sequestration to the use of alien species in poverty alleviation, this book provides a synthesis that will be of value to invasion biologists but also of considerable interest to many others. As an example, concerns about the decline of pollinating insects are echoed around the world. It is important to reflect on the role of invasive alien species alongside other drivers of change in contributing to the observed declines. Similarly, research has been emerging on the way in which the addition of an alien species to a community has profound aboveground and belowground effects on biogeochemical cycles. The chapters in this book reviewing such innovative research will be of critical importance in advancing our understanding.

Alien species, by definition, are species on the move—often crossing continents. The need for collaborations across countries and between academics, practitioners, and policy makers is critical. This book, with 50 contributors spanning 18 countries, highlights the inspiring collaborative nature of research on biological invasions. It is a pleasure to be able to provide support to this network of international biologists through the EU-funded COST Action ALIEN Challenge (www.brc.ac.uk/alien-challenge/home).

NERC Centre for Ecology & Hydrology
Wallingford, UK

Helen E. Roy

Preface

The field of biological invasions arouses considerable interest within different sectors of society. Many scientists are curious to understand how introduced species have been moved across continents by humans, why these species become established in a new region, and what the consequences might be of their interaction with native species and recipient ecosystems. Ecologists and conservationists have for many decades been concerned about the ecological impacts of non-native species on biodiversity as well as on the loss of quality of invaded ecosystems. For example, in Europe there are more than 1000 non-native species with documented ecological impacts.

The terminology regarding biological invasions has been the focus of much discussion. In this book, we have mostly used the term ‘non-native’ (synonyms include alien, non-indigenous, exotic) throughout to describe species introduced to new regions by human activities. Furthermore, we have restricted the use of the term ‘invasive species’ to the subset of non-natives that have impacts on ecosystem services.

Harmful non-native species are not only present in natural ecosystems but are also found in systems that are the key to sustaining our livelihood, including agricultural lands and urban areas. Farmers, veterinarians, epidemiologists, medical professionals, and civil engineers are involved in avoiding, detecting, and managing weeds, pests, and pathogens that interfere with crops, livestock production, infrastructure, and public health. All these impacts have direct economic costs. Such cross-sectorial impacts require a multidisciplinary approach to the field of biological invasions to evaluate and mitigate the consequences of harmful non-native species.

Despite these concerns, both the numbers and distributions of non-native species continue to increase in most countries of the world to the extent that the biogeographic distinctiveness of different regions is becoming blurred. The general public still maintains a fascination for exotic ornamental plants and companion animals from different countries. In addition, there is considerable interest within industry and government sectors in the deliberate introduction of non-native species for their usefulness as protein source (for human or livestock food) or biofuel production. Even some scientists (who should know better) exhibit enthusiasm regarding the

irreversible ecological changes caused by non-native species and embrace these radically altered ecosystems as novel and inevitable. Yet, recent pest outbreaks and disease epidemics raise awareness of the threat posed by nonnative species.

Non-native species are increasingly a cause of conflict as one sector seeks to introduce species for economic benefit while another group argues against such action because of the potential for environmental harm. Even unintentionally introduced species can be simply viewed as a cost of improved trade that has to be seen against the economic benefits of accessing global markets. Resolving such conflicts are challenging even when the impact of biological invasions can be easily quantified in monetary terms. However, in most cases impacts are difficult to quantify in such simple terms because they affect aesthetics, sense of place, and the value of individual species.

These tangible and nontangible impacts can be framed under the ecosystem services approach. Ecosystem services can be defined as the goods that nature provides to people. The classification of ecosystem services encapsulates the different facets of biodiversity that influence people's lives and well-being. In this book, we used this approach as a guide to highlight the major impacts of the introduction of non-native species on our planet, which include impacts on supporting, provisioning, regulating, and cultural services. This framework allows us to integrate ecological and economic impacts and beyond because the consequences of the introduction of non-native species need to be examined broadly across taxa, across ecosystems, and across disciplines. We hope that this book helps to raise awareness about biological invasions as a human-driven change in the quality of life, and points towards solutions so that we can reap the benefits of non-native species without incurring their costs.

Sevilla, Spain
Lincoln, New Zealand
January 2017

Montserrat Vilà
Philip E. Hulme

Acknowledgments

We thank Daniel Simberloff for supporting this book. We are most grateful to Ignasi Bartomeus, Bryce Buddle, Miguel Clavero, Alison Dunn, Christian Kull, Brendon Larson, Ainhoa Magrach, Cristina Maguas, Anibal Pauchard, Quentin Paynter, Marta Sánchez, Stefan Schindler, Mike Schuster, Yan Sun, Mark Torchin, Stephanie Yelenik, Jacob Weiner, Rieks van Klinken, Brian van Wilgen, and Stephen Woodward for comments that improved early versions of the chapters, and to Sarah Hunger and Gregorio M. Toral for technical assistance with editing.

This book is based upon work from COST Action TD1209: ALIEN Challenge, supported by COST (European Cooperation in Science and Technology). COST is a pan-European intergovernmental framework. Its mission is to enable breakthrough scientific and technological developments leading to new concepts and products and thereby contribute to strengthening Europe's research and innovation capacities.

Financial support has been provided by the Spanish Ministerio de Economía y Competitividad, through the Severo Ochoa Program for Centres of Excellence in RDI (SEV-2012-0262), the project IMPLANTIN (CGL2015-65346-R), and the New Zealand Tertiary Education Commission through its support of the Bio-Protection Research Centre, Lincoln University.

Contents

1	Non-native Species, Ecosystem Services, and Human Well-Being	1
	Montserrat Vilà and Philip E. Hulme	
Part I Impacts on Supporting Services		
2	Changes in Primary Production and Carbon Sequestration After Plant Invasions	17
	Ming Nie, Lei Shang, Chengzhang Liao, and Bo Li	
3	Modification of Habitat Quality by Non-native Species	33
	Jorge L. Gutiérrez	
4	Alteration of Nitrogen Cycling as a Result of Invasion	49
	Pilar Castro-Díez and Álvaro Alonso	
5	Hydrological Impacts of Biological Invasions	63
	Jane A. Catford	
Part II Impacts on Provisioning Services		
6	Decreases in Crop Production by Non-native Weeds, Pests, and Pathogens	83
	Guillaume Fried, Bruno Chauvel, Philippe Reynaud, and Ivan Sache	
7	Impact of Non-native Invertebrates and Pathogens on Market Forest Tree Resources	103
	Marc Kenis, Alain Roques, Alberto Santini, and Andrew M. Liebhold	

8 Interference of Non-native Species with Fisheries and Aquaculture..... 119
 Rodolphe E. Gozlan

9 Impacts of Non-native Species on Livestock..... 139
 Nigel P. French

Part III Impacts on Regulating Services

10 Displacement and Local Extinction of Native and Endemic Species..... 157
 Petr Pyšek, Tim M. Blackburn, Emili García-Berthou, Irena Perglová, and Wolfgang Rabitsch

11 Infections and Diseases in Wildlife by Non-native Organisms 177
 Serge Morand

12 Biological Control Agents: Invasive Species or Valuable Solutions? 191
 Judith H. Myers and Jenny S. Cory

13 Disruption of Pollination Services by Invasive Pollinator Species 203
 Carolina L. Morales, Agustín Sáez, Lucas A. Garibaldi, and Marcelo A. Aizen

14 Impact of Invasions on Water Quality in Marine and Freshwater Environments..... 221
 Pedro Reis Costa, José Carlos Martins, and Paula Chainho

15 Impact of Biological Invasions on Infrastructure 235
 Olaf Booy, Lucy Cornwell, Dave Parrott, Mike Sutton-Croft, and Frances Williams

16 Alterations of Disturbance Regimes by Plant and Animal Invaders..... 249
 Mirijam Gaertner, David C. Le Maitre, and Karen J. Esler

Part IV Impacts on Cultural Services and Human Well-Being

17 The Rise of Non-native Vectors and Reservoirs of Human Diseases 263
 Wolfgang Rabitsch, Franz Essl, and Stefan Schindler

18 Impact of Non-native Animals and Plants on Human Health 277
 Wolfgang Nentwig, Dietrich Mebs, and Montserrat Vilà

**19 Use of Non-native Species for Poverty Alleviation
in Developing Economies..... 295**
Arne B.R. Witt

20 Non-native Species and the Aesthetics of Nature..... 311
Christoph Kueffer and Christian A. Kull

Part V Synthesis

**21 Integrating the Impacts of Non-native Species
on Ecosystem Services into Environmental Policy..... 327**
Philip E. Hulme and Montserrat Vilà

Species Index 343

Subject Index..... 351

Contributors

Marcelo A. Aizen Laboratorio Ecotono, INIBIOMA (CONICET-Universidad Nacional del Comahue), Bariloche, Río Negro, Argentina

Álvaro Alonso Department of Life Sciences, Alcalá University, Alcalá de Henares, Madrid, Spain

Tim M. Blackburn Department of Genetics, Evolution & Environment, Centre for Biodiversity & Environment Research, University College London, London, UK
Institute of Zoology, ZSL, Regents Park, London, UK

Olaf Booy Animal and Plant Health Agency, Sand Hutton, York, UK
Centre for Wildlife Management, School of Biology, Newcastle University, Newcastle-upon-Tyne, UK

Pilar Castro-Díez Department of Life Sciences, Alcalá University, Alcalá de Henares, Madrid, Spain

Jane A. Catford School of BioSciences, The University of Melbourne, Melbourne, VIC, Australia

Fenner School of Environment and Society, The Australian National University, Canberra, ACT, Australia

Department of Ecology, Evolution and Behavior, University of Minnesota, Saint Paul, MN, USA

Biological Sciences, University of Southampton, Southampton, UK

Paula Chainho MARE-FCUL—Marine and Environmental Sciences Centre, Faculdade de Ciências da Universidade de Lisboa, Lisbon, Portugal

Bruno Chauvel Agroécologie, AgroSup Dijon, INRA, University Bourgogne Franche-Comté, Dijon, France

Lucy Cornwell Animal and Plant Health Agency, Sand Hutton, York, UK

Jenny S. Cory Department of Biological Sciences, Simon Fraser University, Burnaby, BC, Canada

Pedro Reis Costa IPMA – Portuguese Institute of Sea and Atmosphere/CCMAR—Centre for Marine Sciences, Lisbon, Portugal

Karen J. Esler Department of Conservation Ecology and Entomology, Centre for Invasion Biology, Stellenbosch University, Stellenbosch, South Africa

Franz Essl Department Biodiversity & Nature Conservation, Environment Agency Austria, Vienna, Austria

Division of Conservation, Vegetation and Landscape Ecology, University Vienna, Vienna, Austria

Nigel P. French mEpiLab, Institute of Veterinary, Animal & Biomedical Sciences, Massey University, Turitea, New Zealand

Guillaume Fried Anses, Laboratoire de la Santé des Végétaux, Unité entomologie et plantes invasives, Montferrier-sur-Lez, France

Mirijam Gaertner Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Matieland, South Africa

Emili García-Berthou GRECO, Institute of Aquatic Ecology, University of Girona, Girona, Catalonia, Spain

Lucas A. Garibaldi Grupo de Investigación en Agroecología (AGRECO), Sede Andina, Universidad Nacional de Río Negro (UNRN) and CONICET, Bariloche, Río Negro, Argentina

Rodolphe E. Gozlan UMR BOREA IRD-MNHN-Université Pierre et Marie Curie, French National Research Institute for Sustainable Development (IRD), Paris, France

Jorge L. Gutiérrez Grupo de Investigación y Educación en Temas Ambientales (GrIETA), San Eduardo del Mar, Argentina

Facultad de Ciencias Exactas y Naturales & CONICET, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina

Cary Institute of Ecosystem Studies, Millbrook, NY, USA

Philip E. Hulme The Bio-Protection Research Centre, Lincoln University, Lincoln, Canterbury, New Zealand

Mark Kenis CABI, Delémont, Switzerland

Christoph Kueffer Institute of Integrative Biology, ETH Zurich, Zurich, Switzerland

Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Matieland, South Africa

Christian A Kull Institute of Geography and Sustainability, University of Lausanne, Lausanne, Switzerland

Centre for Geography and Environmental Science, Monash University, Melbourne, Australia

David C. Le Maitre Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Matieland, South Africa

Natural Resources and the Environment, CSIR, Stellenbosch, South Africa

Bo Li Ministry of Education Key Lab for Biodiversity Science and Ecological Engineering, The Institute of Biodiversity Science, Fudan University, Shanghai, China

Chengzhang Liao Ministry of Education Key Lab for Biodiversity Science and Ecological Engineering, The Institute of Biodiversity Science, Fudan University, Shanghai, China

Andrew M. Liebhold US Forest Service, Northern Research Station, Morgantown, WV, USA

José Carlos Martins CIIMAR/CIMAR—Interdisciplinary Centre of Marine and Environmental Research, University of Porto, Terminal de Cruzeiros do Porto de Leixões, Porto, Portugal

Dietrich Mebs Centre of Forensic Medicine, University of Frankfurt, Frankfurt am Main, Germany

Carolina L. Morales Laboratorio Ecotono, INIBIOMA (CONICET-Universidad Nacional del Comahue), Bariloche, Río Negro, Argentina

Serge Morand CNRS-CIRADAGIRs, Faculty of Veterinary Technology, Kasetsart University, Bangkok, Thailand

Judith H. Myers Department of Zoology, University of British Columbia, Vancouver, BC, Canada

Wolfgang Nentwig Institute of Ecology and Evolution, University of Bern, Bern, Switzerland

Ming Nie Ministry of Education Key Lab for Biodiversity Science and Ecological Engineering, The Institute of Biodiversity Science, Fudan University, Shanghai, China

Dave Parrott Animal and Plant Health Agency, Sand Hutton, York, UK

Irena Perglová Institute of Botany, Department of Invasion Ecology, The Czech Academy of Sciences, Průhonice, Czech Republic

Petr Pyšek Institute of Botany, Department of Invasion Ecology, The Czech Academy of Sciences, Průhonice, Czech Republic

Department of Ecology, Faculty of Science, Charles University in Prague, Prague, Czech Republic

Wolfgang Rabitsch Department Biodiversity & Nature Conservation, Environment Agency Austria, Vienna, Austria

Philippe Reynaud Anses, Laboratoire de la Santé des Végétaux, Unité entomologie et plantes invasives, Montferrier-sur-Lez, France

Alain Roques INRA, UR 633 Zoologie Forestière, Orléans, France

Ivan Sache AgroParisTech, UMR1290 Bioger, Thiverval-Grignon, France
INRA, UMR1290 Bioger, Thiverval-Grignon, France

Agustín Sáez Laboratorio Ecotono, INIBIOMA (CONICET-Universidad Nacional del Comahue), Bariloche, Río Negro, Argentina

Alberto Santini Institute of Sustainable Plant Protection, C.N.R., Sesto Fiorentino, Italy

Stefan Schindler Department Biodiversity & Nature Conservation, Environment Agency Austria, Vienna, Austria

Lei Shang Ministry of Education Key Lab for Biodiversity Science and Ecological Engineering, The Institute of Biodiversity Science, Fudan University, Shanghai, China

Mike Sutton-Croft Animal and Plant Health Agency, Sand Hutton, York, UK

Montserrat Vilà Doñana Biological Station (EBD-CSIC), Sevilla, Spain

Frances Williams CABI, Nairobi, Kenya

Arne B.R. Witt CABI Africa, Nairobi, Kenya