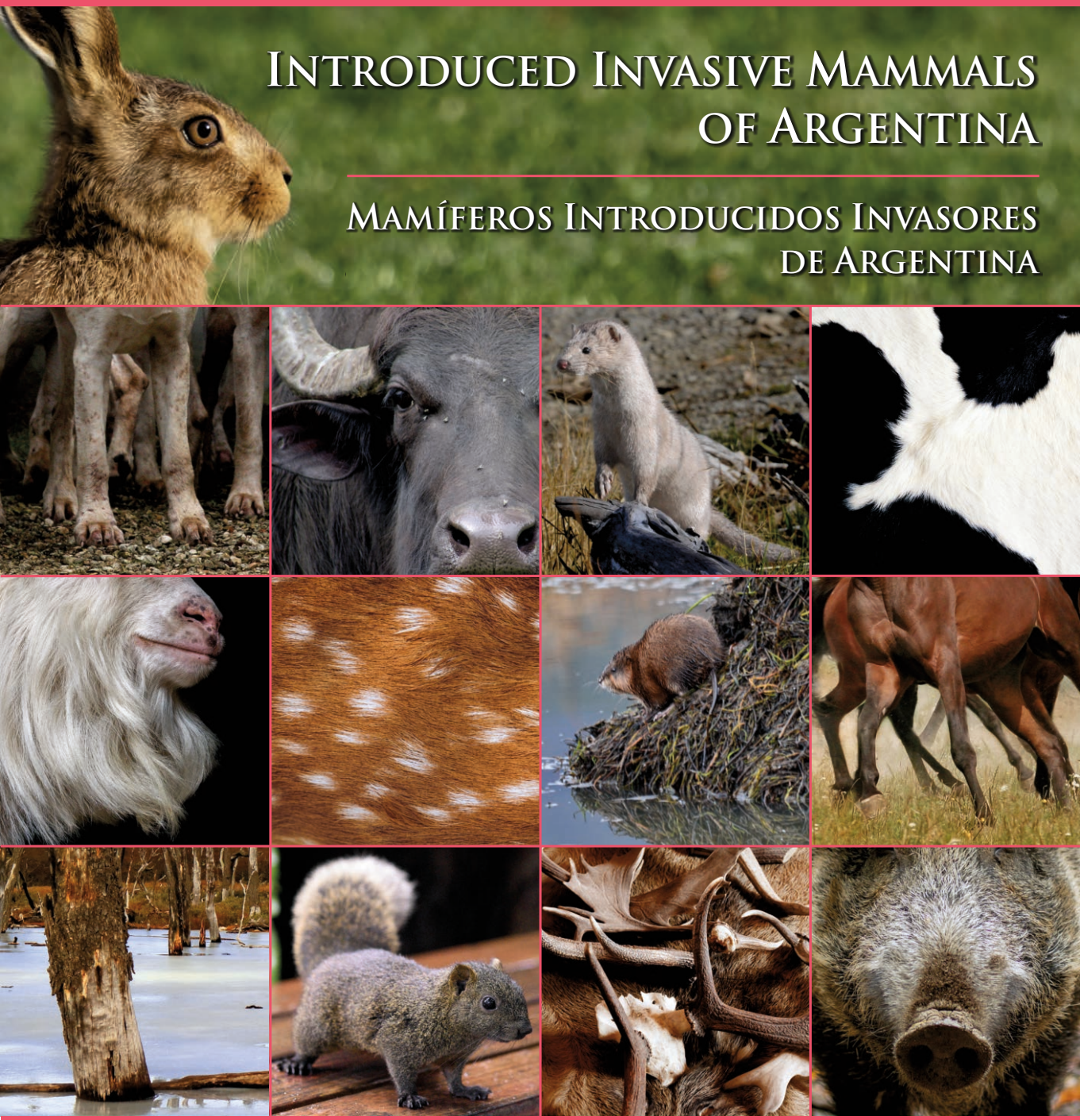
SAREM Series A
Mammalogical Research
Investigaciones Mastozoológicas

Volume 3

Introduced Invasive Mammals of Argentina

Mamíferos Introducidos Invasores de Argentina



Alejandro E. J. Valenzuela, Christopher B. Anderson, Sebastián A. Ballari and **Ricardo A. Ojeda**, Editors

The Argentine Society for the Study of Mammals (Sociedad Argentina para el Estudio de los Mamíferos – SAREM) was created in 1983, and currently has about 300 members from several countries. SAREM is an interdisciplinary society of natural sciences professionals whose main goals are the promotion of scientific and technical research, the consolidation of national collections and research centers, and the publication and diffusion of research on living and/or extinct mammals. SAREM has organized scientific meetings for mammal researchers since 1994, publishes the journals *Mastozoología Neotropical* and *Notas sobre Mamíferos Sudamericanos*, and has edited books on the systematics, distribution and conservation of the mammals of southern South America, including *Libro Rojo de los mamíferos amenazados de la Argentina* (first ed. 2000, second ed. 2012) and *Mamíferos de Argentina. Sistemática y distribución* (2006), as well as contributing to the *Libro Rojo de los mamíferos y aves amenazados de la Argentina* (currently out of print).

» Dr. Alejandro E. J. Valenzuela

Alejandro E. J. Valenzuela is a biologist in the Argentine National Scientific & Technical Research Council (CONICET) and professor at the National University of Tierra del Fuego (UNTDF). He works doing ecological research applied to native wildlife conservation and invasive species management, but also supporting managers and decision-makers to generate conservation strategies.

» Dr. Christopher B. Anderson

Christopher B. Anderson is an ecologist in the Argentine National Scientific & Technical Research Council (CONICET) and a professor at the National University of Tierra del Fuego (UNTDF). Originally from the USA, he has spent his professional career studying the integrated ecological and social dimensions of environmental problems in southern Patagonia.

» Dr. Sebastián A. Ballari

Sebastián A. Ballari is an ecologist and wildlife biologist manager in the Argentine National Scientific & Technical Research Council (CONICET). With an emphasis on the conservation of native ecosystems and their natural processes, his interests include the study of introduced invasive species, wildlife management in protected areas, and effects of global change drivers.

» Dr. Ricardo A. Ojeda

Ricardo A. Ojeda is a biologist at the Argentine Institute of Arid Zones Research (IADIZA) and the Argentine National Scientific & Technical Research Council (CONICET). His main research interests are the ecology of small desert mammals, biogeographic patterns, integrative taxonomy and biodiversity conservation.

Introduced Invasive Mammals of Argentina

EDITED BY

Alejandro E. J. Valenzuela
Instituto de Ciencias Polares, Ambiente y Recursos Humanos (ICPA), Universidad Nacional de Tierra del Fuego (UNTDF)
& Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
avalenzuela@untdf.edu.ar

Christopher B. Anderson
Instituto de Ciencias Polares, Ambiente y Recursos Naturales (ICPA), Universidad Nacional de Tierra del Fuego (UNTDF)
& Centro Austral de Investigaciones Científicas (CADIC), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
canderson@untdf.edu.ar

Sebastián A. Ballari
Parque Nacional Nahuel Huapi (CENAC),
Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)
s.ballari@conicet.gov.ar

Ricardo A. Ojeda
Instituto Argentino de Investigaciones de Zonas Áridas (IADIZA),
Centro Científico Tecnológico (CCT) – Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) – Mendoza
rojeda@mendoza-conicet.gob.ar

SAREM Series A
Mammalogical Research
Investigaciones Mastozoológicas

SAREM Series A
Mammalogical Research
Investigaciones Mastozoológicas
Buenos Aires, Argentina

SAREM – Sociedad Argentina para el Estudio de los Mamíferos
Av. Ruiz Leal s/n, Parque General San Martín. CP 5500, Mendoza, Argentina
www.sarem.org.ar

Introduced Invasive Mammals of Argentina / Alejandro Valenzuela … [*et al.*]. – 1ª ed. – Mendoza : Sociedad Argentina para Estudio de los Mamíferos SAREM, 2023.
Memoria USB, PDF

ISBN 978-987-98497-9-8

1. Mamífero. 2. Animales Exóticos. I. Valenzuela, Alejandro.
CDD 599.0982

Cover collage: Gabriela F. Ruellan

Cover photo credits: Kev on Pixabay (European hare) | Dorota Kudyba (dogs and horses) | Ruediger50 on Pixabay (water buffalo) | Sergio Anselmino (American mink) | Gabriela Ortega (cow hide) | efPercy05 on Pixabay (goat) | suksao on Freepik (chital) | Guillermo Deferrari (muskrat) | J. Cristóbal Pizarro (North American beaver damage) | Peter Chou (Pallas's squirrel) | Public Domain Pictures (red and fallow deer antlers) | marco on Pixabay (wild boar)

SAREM Series A
Mammalogical Research
Investigaciones Mastozoológicas

Introduced invasive species are a major driver of local to global environmental change, including important negative impacts on biodiversity, ecosystem processes, economies, health and other social values. At the same time, however, different social actors can hold diverse representations of these species, particularly of introduced invasive mammals (IIMs). Such divergent values and perceptions can lead to conflicts regarding the management of IIMs, but also invite researchers and managers to be reflexive regarding their own work at a more fundamental level. Therefore, it is key that we advance towards a holistic understanding of IIMs and develop strategies to manage them based on solid technical information and plural perspectives regarding their multiple values. Despite a rich history of initiatives in Argentina to study and manage IIMs, until now there has not been an opportunity to assess the state-of-the-art knowledge in our country. This book seeks to provide rigorous, relevant and legitimate information to support research, policymaking and management decisions regarding IIMs in Argentina. With this objective in mind, the book presents a series of chapters selected to highlight priority topics concerning the conceptualization and implementation of IIM research and management. Then, fact sheets are provided for the different IIMs found in Argentina. Finally, beyond the realm of academic inquiry, the timing of this publication is ideal to re-enforce policy and decision-making, such as the recently approved National Invasive Exotic Species Strategy, which seeks to implement actions and enhance institutional capacities related to invasive species management in Argentina, and the Convention on Biological Diversity's new Global Biodiversity Framework, which also addresses biological invasions as part of broader efforts to attain the 2050 Vision for Living in Harmony with Nature.

Dr. Alejandro E.J. Valenzuela
Dr. Christopher B. Anderson
Editors, Vol. III SAREM Series A

Contents

Foreword

Biological invasions by introduced species are one of the great changes rapidly transforming the globe today, with innumerable impacts on economics, human health, ecosystem services, and biodiversity. Mammals are among the most impactful of invasive species, transmitting diseases to humans, livestock, and native animals, trampling native grasslands, voraciously devouring vegetation from groundcover to saplings of forest trees, fouling water, causing erosion, and preying on and outcompeting native animals. They were among the first species humans introduced worldwide and in Argentina, both deliberately (*e.g.*, livestock) and inadvertently (*e.g.*, rats and mice). They have been introduced for sport (*e.g.*, deer, boar) and companionship (*e.g.*, cats, dogs), or simply as attractive ornamentals (*e.g.*, squirrels). Some that are meant to be kept in captivity, such as cats, dogs, and squirrels, escape and establish feral populations.

Argentina looms large in the history of biological invasions by introduced mammals. The earliest permanent European settlers of Buenos Aires in 1580 discovered huge herds of feral horses already on the pampas, and soon after, Vázquez de Espinoza described feral horses in Tucumán that were "in such numbers that they cover the face of the earth…". Many sheep were in Tucumán as well at that time, and of course later sheep were enormously numerous in Patagonia, effecting huge changes in the vegetation and driving land degradation and desertification to this day. When Charles Darwin visited the La Plata region in 1832 during the voyage of the Beagle, he reported that "…countless herds of horses, cattle, and sheep, not only have altered the whole aspect of the vegetation, but they have almost banished the guanaco, deer and ostrich. Numberless other changes must likewise have taken place; the wild pig in some parts probably replaces the peccari; packs of wild dogs may be heard howling on the wooded banks of the less-frequented streams; and the common cat, altered into a large and fierce animal, inhabits rocky hills."

Approximately 40 mammals have been introduced to South America, of which 25–30 have established populations; most of these are in the Southern Cone. In Argentina, I count 23 successfully introduced mammal species, including feral cats, dogs, and cows. Many, such as rats, rabbits, boar, and goats, are widely distributed around the world. By contrast, the hairy armadillo has been introduced nowhere else but from the mainland of Patagonia to Tierra del Fuego Island. Strikingly, except for the rats and house mouse, all these mammals were brought to Argentina deliberately; this is very different from, say, introduced insects. A few of these invasive mammals, like the squirrel, were not intended to be released, but I hesitate to term such invaders truly "accidental," because the people who brought them should have realized that escapes or later releases were almost inevitable. Of course, almost all of these mammals were introduced before the late twentieth century, which was when most scientists and the public began to recognize the extent and importance of impacts of introduced species. However, the squirrel and armadillo introductions were recent enough that potential impacts should have been foreseen. Things could be worse, of course—mammals deliberately brought to Argentina that either were released, but did not establish persistent populations or have not yet escaped from hunting preserves include reindeer, silver fox, mule deer, African buffalo, white-tailed deer, Père David's deer, thar, barbary sheep, wisent, mouflon, chamois, and ibex.

The technology of eradicating introduced invasive mammals has made enormous strides in the last thirty years—at least 31 mammal species have been eradicated from islands worldwide, including relatively large islands like South Georgia. Both Norway and ship rats have been eradicated hundreds of times, and house mice about 100 times. Most large mammals, such as deer and horses, are technologically easier eradication targets—many can simply be tracked and shot, for instance. However, mammals more than any other introduced species pose the complication that many people—especially hunters—simply do not want to eradicate them, and many animal welfare advocates, even those recognizing the damage some invaders cause, object to eradicating them by the only currently feasible means—killing them, humanely if possible. Even rat eradication has been impeded on animal rights/animal welfare grounds, and free-ranging dog and cat populations frequently are seen more as animal welfare issues than as conservation problems to broad sectors of some societies. In Argentina, the problem of implementing feasible eradication programs for invasive mammals is epitomized by the rather schizophrenic attitude taken by the National Parks Administration (Administración de Parques Nacionales – APN) towards red deer. The APN's conservation imperative is supported by the section of Law #22,351 that forbids propagating introduced animals, yet red deer, known to damage native species and ecosystems, are managed in Lanín National Park to foster ongoing hunting, and even to improve the size and quality of the deer for better hunting trophies. Additionally, there is often inconsistent and inadequate funding for managing and eradicating invasive mammals in protected areas, almost always constituting a supervening impediment even when a rational and effective goal is stated.

Argentine scientists have participated heavily in the rapid growth of modern invasion science since its inception in the 1980s, and they and overseas colleagues have conducted substantial research on the biology and impacts of many of the introduced invasive mammals in Argentina, as well as other invasive species. Some of the threats posed by these mammals have even become widely known to the general public in Argentina and beyond—the spread of the beaver from Tierra del Fuego to the mainland has been an international news story. *Introduced Invasive Mammals of Argentina* is therefore an exciting and timely addition to the literature on invasions in southern South America for both the Argentine public (and its political representatives and environmental managers) and scientists worldwide. The many authors assembled for this book explore how these biological invasions happened in the first place, how they spread, what they do to biodiversity, ecosystems, and human enterprises, what has been done about them so far, what can be done about them now, and what might be done with them in the future. The editors and authors are to be congratulated for an excellent exposition of the Argentine part of a growing global phenomenon.

Daniel Simberloff
Nancy Gore Hunger Professor of Environmental Studies
Department of Ecology and Evolutionary Biology
University of Tennessee
Knoxville, TN 37996

2 RECONCEIVING BIOLOGICAL INVASIONS AS A SOCIO-ECOLOGICAL PHENOMENON USING THE CASE STUDY OF BEAVERS IN PATAGONIA

RECONCEPTUALIZANDO LAS INVASIONES BIOLÓGICAS COMO UN FENÓMENO SOCIO-ECOLÓGICO USANDO EL CASO DE ESTUDIO DEL CASTOR EN PATAGONIA

Christopher B. ANDERSON[1,2] and J. Cristobal PIZARRO[1,*]

[1] Austral Center for Scientific Research (CADIC – CONICET), Houssay 200, 9410 Ushuaia, Argentina.
canderson@alumni.unc.edu

[2] Institute of Polar Sciences, Environment and Natural Resources, National University of Tierra del Fuego, Fuegia Basket 251, 9410 Ushuaia, Argentina.

*Current affiliation: Laboratorio de Estudio del Antropoceno (LEA), Departamento de Manejo de Bosques y Medioambiente, Facultad de Ciencias Forestales, Universidad de Concepción, Victoria #631, Barrio Universitario, Casilla 160-C, 4030000, Concepción, Chile.
jpizarrop@udec.cl

Abstract. The ways we conceive biodiversity and nature determine how we investigate and manage it. In the case of introduced invasive species, they have mostly been viewed with an ecological lens, even those with clear ecological and social impacts, such as the North American beaver (*Castor canadensis*) in Tierra del Fuego. We use this case to consider how re-conceiving biological invasions as socio-ecological phenomenon, with multiple human and natural drivers and outcomes, can improve holistic and predictive capabilities of integrated research and management. Specifically, we approach the issue by evaluating how scientific paradigms in ecology have incorporated humans into ecosystems (or not), subsequently applying these perspectives to the conceptualization, study and management of *C. canadensis* in southern Patagonia. We found that most research and management efforts concerning the invasive beaver has been from a perspective that either ignores the human dimension or conceives of humans (and beavers) as agents of ecosystem disturbance. Recently, the multi-faceted roles of humans have been recognized more explicitly. However, social research has been catalyzed largely by a binational political agreement between Argentina and Chile to eradicate beavers and restore "natural" ecosystems, which still conceives of humans as separate from, or disturbers of, nature. Therefore, even though emerging perspectives of beaver research and management increasingly include a human dimension, our evaluation of this case study still finds significant limitations to fully integrated research and applications due to an unconsolidated paradigm of humans as "co-participants" in ecosystems. From this analysis, we propose three lessons that can help re-conceive biological invasions as socio-ecological phenomenon: 1) build a transdisciplinary research agenda, 2) create communities of knowledge between academics, decision-makers and other social actors and 3) teach environmental history and philosophy in the natural science curricula that produce most biological invasion researchers and managers.

Resumen. La forma en que conceptualizamos la biodiversidad y la naturaleza influye fuertemente la manera en la cual la estudiamos y manejamos. Las especies introducidas e invasoras, en este sentido, han sido analizadas principalmente desde la ecología, cuya conceptualización de la naturaleza ha excluido, en gran parte de su historia, a los seres humanos. Por esta razón, a pesar de los grandes avances en el conocimiento de las invasiones biológicas como un fenómeno ecológico, aun sabemos relativamente poco sobre los impactos y repercusiones sociales, culturales y económicas de la introducción de especies en nuevos territorios. Un caso emblemático es el castor norteamericano (*Castor canadensis*), introducido en 1946 desde Canadá al Archipiélago de Tierra del Fuego, territorio transfronterizo entre Argentina y Chile. Usamos este caso para considerar cómo la re-conceptualización de las invasiones biológicas como fenómenos socio-ecológicos podría mejorar las capacidades predictivas y de planteamiento holístico de la ciencia integrada al manejo y las políticas públicas de estas especies. Abordamos este tema, primero, a través de la evaluación de la inclusión de los seres humanos en los paradigmas científicos de la ecología.

Se encontró que los paradigmas dominantes de esta disciplina reconocen a los seres humanos en relación a la naturaleza como 1) promotores de cambio o 2) receptores de beneficios (o perjuicios). Una perspectiva emergente de los humanos es como 3) co-participantes, la cual puede ser identificada a través de la integración de perspectivas de disciplinas sociales, como la geografía humana y la etnoecología. Esta última conceptualización de la relación humano-naturaleza sería también congruente con los cambios sociales y culturales relacionados con la interculturalidad de las sociedades globalizadas y la expansión de la influencia humana sobre la biosfera en el Antropoceno. Luego, aplicamos estas tres perspectivas para analizar la forma en que los castores han sido estudiados y manejados en la Patagonia, revisando además la historia de su introducción e investigación.

Encontramos que la mayor parte de la investigación fue realizada bajo el concepto de «castores como ingenieros ecosistémicos». A partir de estas investigaciones, y en estrecha relación con la aprobación de un acuerdo binacional entre Argentina y Chile para su erradicación en 2008, se lograron importantes avances en el conocimiento ecológico del castor, pero se ignoraron, en gran parte, los aspectos sociales relacionados con su introducción y expansión hacia el continente, no confrontada por las autoridades por más de 60 años. Bajo la segunda aproximación sobre los daños o servicios del castor, agrupamos los estudios que midieron las percepciones de actores sociales específicos (p.ej. estancieros) sobre el efecto que provocan los castores en sus predios. Consideramos que la tercera perspectiva de humanos como co-participantes tiene escaso desarrollo, pero bajo esta categoría agrupamos trabajos recientes en antropología, estudios de la ciencia y la tecnología, y otras investigaciones sobre las percepciones de diversos grupos sociales sobre el castor. Además, recopilamos antecedentes que demuestran la participación de esta especie en la oferta turística y el sentido de pertenencia de los habitantes de Ushuaia en Argentina e Isla Navarino en Chile.

En base al análisis de este caso, mostramos la poca claridad que tenemos sobre la dimensión humana de las invasiones biológicas, y elaboramos tres propuestas desde las lecciones aprendidas de este ejemplo para avanzar en su reconceptualización: 1) construir una agenda de investigación transdisciplinaria, 2) crear comunidades de conocimiento con académicos, tomadores de decisiones y una variedad de actores sociales, y 3) incluir la enseñanza de la historia y la filosofía ambiental como herramienta crítica en el currículo de las ciencias naturales que formará a una nueva generación de investigadores de especies invasoras y gestores de recursos naturales capaces de generar estrategias de manejo adaptativas y socialmente vinculantes en el Antropoceno.

Introduction

References to species "invasions" are not new in the ecological scientific literature. The term is often traced to Charles Elton's (1958) seminal book, entitled *The ecology of invasions by animals and plants*, but earlier antecedents referring to the effects of species introductions were enunciated by Charles Darwin and others as early as the mid-1800s (Cadotte, 2011). However, invasion biology did not consolidate as a sub-discipline of ecology until the 1980s (Huenneke *et al.*, 1988), and its establishment coincides with broader academic efforts at that time to apply largely ecological research to identify and confront major environmental problems (see also the history of conservation biology: Meine *et al.*, 2010). In this context, the spread of introduced species around the globe came to be recognized as a major driver of global ecological change and biodiversity loss, via both species extinctions and biotic homogenization (Vitousek *et al.*, 1997; McKinney and Lockwood, 1999).

Today, invasion biology is a prominent area in ecology, and biological invasion studies account for one-quarter of all ecology publications in Latin America and the Caribbean (Pauchard *et al.*, 2011). Furthermore, articles on invasion biology have great impact, being more cited than those in other prominent areas like population biology or even climate change (Pysek *et al.*, 2006). Indeed, the study of biological invasions has become both productive and influential, with its own journals (*e.g.*, *Diversity and Distributions*, *Biological Invasions*, *NeoBiota*), textbooks (Williams, 1996), research centers and academic conferences (*e.g.*, South Africa's Centre for Excellence in Invasion Biology, the Island Invasive Conference, among others).

Notwithstanding its history of academic success and institutionalization, invasion biology has been criticized by some for being conceptually ambiguous (Woods and Moriarity, 2001; Brown and Sax, 2004), practically ineffective (Davis *et al.*, 2011), and socially or ethically controversial (*e.g.*, Mackenzie and Larson, 2010, see also review in Estévez *et al.*, 2015). These concerns, in turn, brought attention to previously unaddressed dimensions of the biological invasion phenomenon. For example, despite studies that demonstrate invasive species' negative ecological effects, ethnobotanists Pfeiffer and Voeks (2008) point out that for different social actors the cultural effects of biological invasions can indeed be negative, but also neutral or even positive. Plus, only 5–20% of all introduced species become problematic (IUCN 2017).

Yet, multiple literature reviews from regional (Patagonia: Anderson and Valenzuela, 2014), national (Chile: Quiroz *et al.*, 2006) and international scales (Latin America and the Caribbean: Pauchard *et al.*, 2011; global: Estévez *et al.*, 2015) have shown that dominant approaches to both the research and management of biological invasions are skewed towards natural science-based, descriptive quantifications of invasive species' environmental impacts. On the other hand, more mechanistic ecological work, explaining the biological invasion process and including socioeconomic and cultural aspects, has been relatively neglected (García-Díaz *et al.*, 2021). Arguably, it is precisely by labeling, highlighting and orienting our attention towards the negative aspects of the invasion phenomenon that we may be hindering our ability to holistically address the "problem" of biological invasions at

the multiple scales and dimensions that it occurs (see extensive work by Larson, B. beginning in 2005 on the biological invasion metaphor).

Despite its biological bias (or perhaps due to it), invasion biology has been effective at positioning this issue as a problem for decision-makers at various political scales. Globally, for example, the discourse on biological invasions appeals to many countries' national security concerns, because the harm to local biodiversity and degradation of ecosystems by introduced invasive species represents a loss to the country's biological heritage, including water, food, and economic security (*e.g.*, Paini *et al.*, 2016). Indeed, we find the issue of biological invasions expressed in various policy-making structures at national (*e.g.*, USA's National Invasive Species Council) and regional levels (*e.g.*, European Commission Committee on Invasive Alien Species). Plus, it has been codified into international policy instruments (*e.g.*, the Convention on Biological Diversity, CBD 1992) and multilateral working groups (*e.g.*, IUCN's Invasive Species Specialist Group – ISSG, see also IUCN 2017). Indeed, the CBD's Aichi Target #9 states that 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."

However, even the policy emphasis of this biological approach is focused on generic effects of invasive species (*i.e.*, to invade, to threaten) regardless of their social perceptions, local issues and feasibility and desirability of control and eradication measures. Campaigning for the eradication of agricultural pests, such as insects or weeds, is not the same as for charismatic animals (see García-Quijano *et al.*, 2011, see also Guichón *et al.*, this volume); likewise, carrying out an invasive species control program in a remote protected area is not the same as on an inhabited island or populated suburban area. Indeed, both human and biophysical geography are highly relevant to the success or failure of invasive species management, and perhaps part-and-parcel of both the problem and the solution (Estevez *et al.*, 2015). Therefore, overcoming invasion biology's inherited ecological bias is imperative not only for how we understand and study invasive species, but also how we prevent or manage them.

These global tendencies are also mirrored at the sub-regional and national levels in South America. For instance, the Argentine and Chilean governments signed a bilateral agreement to eradicate introduced North American beavers (*Castor canadensis*) to restore invaded ecosystems in southern Patagonia (Menvielle *et al.*, 2010; Malmierca *et al.*, 2011). This agreement was almost entirely informed by ecological data, science and perspectives.

The beaver was introduced to the Argentine portion of Tierra del Fuego in 1946, and for more than 50 years this biological invasion, and its noticeable effects, went mostly unchallenged. Beginning in the late 1990s, however, ecological research positioned this issue and gave rise to the current agreement, which presumes that the eradication of beavers will permit the restoration of native *Nothofagus* forests. However, little consideration was given to the multi-faceted ways that this ostensibly "biological" problem is both the cause and the outcome of interwoven human and natural processes. For example, the absence of a local hunting-trapping culture, the broader program feasibility (biological, physiological, institutional, and financial) and the ultimate desirability (social, cultural, ethical) of eradication/restoration were not considered sufficiently, even for the ostensibly long-term ecological

goal of restoring "natural" ecosystems. Furthermore, beyond the authorities, diplomats, natural resource managers, biologists and conservationists involved in the bilateral process that produced the agreement, the engagement and participation of other stakeholders (*e.g.*, local communities, ranchers, tourism operators) was consigned to one clause concerning "educating the public" to encourage their support (see full text at Ministerio de Relaciones Exteriores – Chile, 2008).

The introduction of North American beavers from Canada to Tierra del Fuego constitutes a crucial historical moment in the construction of today's southern Patagonian landscape (see also Archibald *et al.*, 2020). First, as ecologists and later as socio-ecological researchers, we have worked for nearly two decades to understand the historical and present context of this biological invasion. We have discussed the issue in different venues, from local to international levels, and with different audiences, from scientific conferences to decision-making workshops and public seminars and talks. By associating our research with different audiences, we started to understand and compile historical antecedents about southern Patagonia and beaver introduction. Together, these historical processes and research findings comprise a narrative regarding beavers on both social and scientific levels. At the same time, we began to recognize the place and role different actors play in this story. In this context, as a case study, the beaver invasion also helps reveal the complex mixture of issues, beyond its mere ecological impact, that require our attention regarding the conceptual, research, societal, and practical levels of this problem. We believe that an analysis of this case may also help other scientists and practitioners broaden their understanding of biological invasions to recognize and confront them as socio-ecological phenomena. Doing so will require the engagement of other disciplinary experts and social actors, thus expanding human-nature paradigms beyond ecology.

In this chapter, we set out to elucidate how the study of this "problem" is influenced by our conceptualization of both "invasive species" and "nature" in Patagonia. To position this case study in a broader disciplinary context, we first reviewed human-nature paradigms in ecology; then, we organized the examples of beaver invasion research and management based on different ways in which humans and nature are conceived in recent scholarship, including: 1) humans as "drivers" of ecosystem change and 2) humans as "recipients" of ecosystem (dis)services. We also include a third point of view, humans as "co-participants" in socio-ecosystems (Fig. 1), as an inter- or transdisciplinary approach including perspectives traditionally found in disciplines like human geography and the humanities. We expected to find that the scientific literature and management efforts on biological invasions continue to embody the historical bias in ecology-related sciences that highlights humans' role as disturbance agents (*i.e.*, drivers), while emerging social sciences and humanities perspectives, which bring to light other aspects of human agency in nature, including the benefits we receive from it and even our co-participation with and co-production of nature (see Anderson *et al.*, 2021), would be less represented. Via the evaluation of these conceptual issues as they relate to the practice of science and management of beavers in southern Patagonia, we conclude by proposing guidance on developing a new agenda that views biological invasions as a socio-ecological phenomenon.

Paradigm	Emphasis on humans	Study unit	Research topics regarding biological invasions	Conceptual models
"Old" balance of nature paradigm	Humans omitted from ecosystems	"Natural" ecosystems	• Natural history of native ecosystems • Study and conservation of "pristine wilderness" areas	a. Humans Nature
"New" flux of nature paradigm	Humans as drivers of ecosystems	"Natural" and anthropogenic ecosystems	• Invasive species autecology • Invasive species impacts • Native ecosystem ecology • Eradication techniques • "Natural" ecosystem restoration	b. Humans → Nature
	Humans as recipients of ecosystems	"Natural" and anthropogenic ecosystems	• Ecosystem services • Ecological economics • Social perceptions • Environmental psychology	c. Humans ← Nature
	Humans as co-participants in ecosystems	Systems with "historical" and "novel" biotic, social & cultural assemblages	• Values of nature • Conservation policies • Community-based management • Decision-making • Justice & power relationships • Sense of place • Governance	d. Humans ↔ Nature

Figure 1. The balance of nature paradigm, which largely viewed humans as separate from nature (**a**), has been replaced by a flux of nature approach, where humans are part of ecosystems (**b-d**). However, the ways humans are conceived even as integrated parts of ecosystems can vary from humans as disturbance agents (**b**) to humans as recipients of ecosystem services (**c**) and disservices and to humans as co-participants (**d**). Such understandings of the human-nature relationship are not only conceptual or semantic, but also have practical implications for the basic study unit we address as scientists and the research topics that are considered valid.

A brief history of human-nature paradigms in ecology

Throughout its history, the scientific field of ecology has viewed humans as both a part of and separate from nature (Aggestam, 2015). While some early founders of the discipline explicitly called for the "study of man and nature (as a unit, not separately)" (Odum, 1953) and declared that "[e]cology occupies a middle ground between the physical, biological, and social sciences, and must deal with human values" (Adams, 1940), the reigning approach to ecology for most of the 20th century focused researchers' efforts on the study of self-contained, static ecosystems that were "natural" and largely excluded human influences (MacIntosh, 1985, Fig. 1a). This view of ecosystems can be termed the "balance of nature paradigm." Plant ecologist F. E. Clements (1874–1945) was influential in this early ecology paradigm via his writings on the study of vegetation succession towards climax communities. In this view, biodiversity was driven by a teleological processes (*i.e.*, nature's own apparent purpose or goal) towards maturity—or rather the final expression of how nature "should" express itself (*i.e.*, without human interference).

By the 1980s, and partially as a consequence of a new social imaginary regarding a global "environmental crisis" that arose in the 1950s and 60s in developed countries (Estenssoro Saavedra, 2007), scholars detected a paradigm shift in ecology and an increasingly explicit recognition of the role of humans in nature. After decades of ecological research under the "Clementsian" paradigm, in the 1980s and 1990s, ecosystems came to be re-conceived of as changing and inter-connected, instead of tending towards a pre-determined pathway to

a final (and hypothetical) state (Pickett and Ostfeld, 1995). Humans, at different intensities and scales, undoubtedly had always been key players in many ecological processes, which vindicated ideas that were contemporary with Clements', specifically H.A. Gleason's (1926) postulates that ecosystems were heterogeneous, stochastic and dynamic. However, it was not until the last part of the 20th century that this perspective became dominant in ecological research (MacIntosh, 1985, Fig. 1b–d).

Today, rapid change and dynamism have become more profoundly characteristic in our conceptualization of the modern world through prominent concepts like the Anthropocene (Crutzen, 2002) and novel ecosystems (Hobbs *et al.*, 2006), which have been coined in the new millennium to emphasize the role of humans as the principal "driver" of ecological change, even at the planetary level (Fig. 1b). Yet, it is important to note that in this same period, the concept of ecosystem services also arose (largely in ecological economics) to link ecosystem feedback loops with human society (Norgaard, 2010). More broadly understood, though, the ecosystem services concept allows the identification of a network of benefits that nature provides to human life, both as a source of supporting natural resources and cultural meaning and social relationships (Pascual *et al.*, 2017) (*i.e.*, humans as "recipients," Fig. 1c).

Overall, understanding the history of ecological thought and of the broader social imaginaries of human-nature relationships allows us to find multiple ways of integrating humans into nature. Such an understanding provides different perspectives not only of how the world "is," but also the way we "ought" to conduct our research and management actions. For instance, scholars, with European heritage in the Americas, seeking the "balance of nature" concept, imagine ecosystems with minimal human impact, but in this process obviate millenary knowledge and interactions that many human societies have and have had with nature, including historical and large ecosystems transformations by local communities and Indigenous peoples. As a case in point, the Yucatán Peninsula's forest was only recently recognized as a "Mayan forest garden" versus a "jungle" (Ford and Nigh, 2009). On the other hand, even when we see humans as an agent mostly of change, it makes a difference if we conceive them as "disturbers" of nature or "drivers" that solely structure ecosystems. This second perspective lead Ellis and Ramankutty (2008) to reconceive biomes as "anthromes" and further to the recognition that human-created landscapes and biotic assemblages have existed in some places for thousands of years (Ellis *et al.*, 2010).

Human-nature paradigms also have influenced the application of ecological sciences on environmental management. In the applied field of conservation biology, Mace (2014) describes a time sequence from the 1960s till now that in many ways reflects the conceptualizations outlined above for the related field of ecology—passing from "nature for itself," to "nature despite people," to "nature for people," and "nature and people." Currently, conservationists are debating the multiple implications of a "nature and people" approach, including controversial proposals like "New Conservation" (Kareiva *et al.*, 2012) that seek to fully integrate Modernity's proposal of managing (even domesticating) nature and rethink the meaning of nature conservation into the future towards fostering global human welfare (Kareiva *et al.*, 2007).

Researchers from social sciences, the humanities, and interdisciplinary fields, such as human geography, environmental psychology, agroecology and ethnobiology, also have examined human-nature relationships in different cultures and epochs (Sconnes, 1999; Pretty, 2011). They too found that human societies and cultures have reciprocally shaped and been shaped by their relationship with biodiversity and ecosystems (Descola and Palsson, 1996; Ingold, 2000). Under this lens, the ideas of "nature for itself" and "nature and people" are largely cultural, and it has been empirically demonstrated, for example, by contrasting landscape preferences among people with different cultural backgrounds (Buijs *et al.*, 2009). Indeed, the idea of nature being "co-produced" (see Hinchliffe, 2007) with humans as "participants" (Fig. 1d) seems more culturally neutral and perhaps more appropriate to the current status of the planet, considering the global extent of human migration (Vertovec, 2007) and anthropogenic impact over ecosystems (Ellis and Ramankutty, 2008; Ellis *et al.*, 2010).

In synthesis, the field of invasion biology has engaged with and responded to these broader conceptual shifts (Fig. 1) and also has confronted epistemological and practical controversies regarding its future (*e.g.*, Larson, 2005; Davis *et al.*, 2011; Simberloff *et al.*, 2011). Therefore, efforts to conceptually and practically include a more socially-integrated and culturally-aware image of humans and nature are still needed. In the following sections, we seek to contribute to this academic and management debate by exploring how different human-nature paradigms relate to our current understanding of the biological invasion of North American beavers in Patagonia and what those insights can teach us for the future of addressing this issue more holistically, effectively and ethically.

Humans as "drivers" of ecological change

An invasive ecosystem engineer. Early scientific research on North American beavers in Patagonia was focused on the species' basic population ecology. For example, Lizarralde (1993) and Skewes *et al.* (2006) published seminal studies of the abundance, density and distribution of beavers in the archipelago, finding that by the late 1990s, beavers had colonized watersheds at densities on the high end of values reported in North America. Later, Anderson *et al.* (2006a) and Wallem *et al.* (2007) showed that the invasion's extent encompassed almost the entire archipelago, with the exception of the Wollaston Islands and Staten Island, and had even occupied the mainland south of Punta Arenas City, Chile by the mid-1990s. Ecologists subsequently began to characterize the beaver under the rubric of an "ecosystem engineer" for its ability to create, alter and destroy ecosystems (*sensu* Jones *et al.*, 1994). Within this body of publications, we find a large number that prioritized the quantification of ecological impacts, but to a lesser degree there are also studies on the underlying mechanisms to explain the beaver's role as an invasive ecosystem engineer in new aquatic and riparian ecosystems (Anderson *et al.*, 2009).

For instance, research shows that beavers reduce stream benthic macroinverbrate diversity by one-third, compared to un-impacted reaches. However, secondary benthic production in beaver ponds was increased by an order of magnitude (Anderson and Rosemond, 2007). Furthermore, beavers simplified pond benthic food webs in their new environment, not only lowering taxonomic diversity, but also decreasing the number of functional feeding

groups (Anderson and Rosemond, 2010). At the same time, though, stream sections immediately downstream of beaver ponds displayed largely similar conditions to un-impacted sites. Based on these data, Anderson and Rosemond (2007) proposed that the mechanism by which beavers differentially affect stream biodiversity and ecosystem function in ponds is via the increase in benthic organic matter, which homogenizes substrate microhabitat for benthos, thereby reducing diversity. At the same time, beaver impacts increased benthic basal resources, thereby enhancing energy flow and the function of secondary production.

Overall, at the patch scale (*i.e.*, stream reaches, beaver ponds), beaver invasion produces the predictable effect of converting lower order streams to the conditions more representative of lentic (*e.g.*, ponds) or high order sections of the watershed. In so doing, beavers transform high latitude aquatic ecosystems (with lower rates of secondary production and decomposition) to values that are in the median of global studies. Consequently, in essence, beavers functionally converted "sub-polar" streams to "temperate" streams (Anderson and Rosemond, 2007). Additionally, considering that beaver ponds are created in a post-glacial landscape with other lentic features, such as wetlands, peat bogs and lakes, it was found that beaver ponds had a similar biotic community to other lentic habitats, but significantly higher retention of organic matter. Therefore, the effect of beavers at the landscape-scale in Tierra del Fuego did not impact benthic biodiversity, but did enhance carbon retention at the watershed scale by an average of 60%, even though the ponds themselves only constituted 10% of the stream networks total length (Anderson *et al.*, 2014).

The studies looking at beavers as a driver of ecological change have also quantified their impact to the riparian zone has the largest alteration to sub-Antarctic forests in the Holocene. In total, approximately 40% of riparian forests have been affected (Anderson *et al.*, 2009), and on the Argentine side of the archipelago this constitutes 30,000 ha that have been impacted (Henn *et al.*, 2016). Studies have also shown that beaver meadows persist as an "alternative stable state" for at least 20 years (Wallem *et al.*, 2010). In particular, the two dominant tree species (*Nothofagus pumilio* and *N. betuloides*) do not regenerate well in these new conditions. Nonetheless, *N. antarctica*, the third tree species found in the archipelago, has two adaptations that make it more resilient; it is both adapted to saturated soil conditions and also has the capacity to sprout from roots and stumps (Anderson *et al.*, 2006b).

Humans as "recipients" of ecosystems

Services and disservices from nature. In TDF, the way humans relate to nature generally and invasive species specifically is a nascent topic of scientific inquiry. Recent studies have begun to delve into how specific stakeholder groups perceive beaver as a threat or benefit, and how these views influence the support control or eradication actions. An intensive and extensive study that conducted interviews and surveys of ranchers in both the Argentine and Chilean portions of the archipelago, demonstrated that 67% supported beaver eradication (Santo *et al.*, 2015), but these same ranchers simultaneously expressed both positive and negative values regarding beavers on their land (Santo *et al.*, 2017).

One management proposal for biological invasions, which seeks to conceive humans as recipients of nature and not only drivers of change to be controlled, is known as human-centered design (Sorice and Donlan, 2015). This methodology has begun to be applied in

the study of beavers in southern Patagonia and sets out to not only determine local knowledge or opinions regarding biological invasions, but also integrates stakeholder preferences for specific aspects of management programs themselves to design them in such a way as to be complementary and amenable to stakeholders' own activities. As such, this approach has the potential to attain greater social support, or "buy-in," and thereby avoid inoperable plans and social conflicts (see Estévez *et al.*, 2015; see also Scorolli, this volume). In the case of Fuegian ranchers, while 67% supported the idea of eradication, it was possible to detect specific program elements that could be modified to enhance their willingness to participate in such initiatives, including increased payments, decreased landowner involvement and increased belief in the probability of success (Santo *et al.*, 2015).

Another way to address how this biological invasion affects what humans receive from nature is to calculate their willingness-to-pay for potential management efforts. In southern Chile, researchers determined that the monetary value society is willing to contribute for the restoration of beaver-impacted forests impacted totals over seven million US dollars (Soto Simeone and Soza-Amigo, 2014). The survey respondent valuation of forests prioritized non-instrumental values, separating out into 48% inheritance value (conservation for future generations), 18% option value (conservation for the possibility to enjoy or visit them in the future), 17% existence value (conservation for the forests intrinsic worth regardless of humans) and 16% direct and indirect uses (conservation for recreation, tourism, science, etc.). Interestingly, while wealthier socio-economic groups were willing to pay more in absolute terms, the lowest strata were willing to pay a higher percentage of their total income.

Humans as "co-participants" in socio-ecological systems

Social and cultural relationships with nature. As of yet, the idea of people co-producing ecosystems with invasive species in southern Patagonia has not been fully explored or researched (but see emerging work, such as Dicenta, 2021). However, we found some insights in qualitative studies and surveys conducted in the small, isolated town of Puerto Williams (Chile, human population 2,000) on Navarino Island, and in Ushuaia (Argentina, human population 60,000) on Tierra del Fuego Island. In Puerto Williams, Berghoefer *et al.* (2008) found that the island's different social groups maintain diverse relationships with nature and consequently develop divergent valuations of invasive species. Indeed, as another study puts it, we can draw a distinction between the relationships with nature from those for whom nature is experienced by direct interaction and senses (*i.e.*, local communities) and others that see a global, endangered nature in need of conservation mediated by acquired knowledge (*i.e.*, scientists, conservationists) (Berghoefer *et al.*, 2010). In the former, invasive species, like the beaver, generate an emotional and familial response (*i.e.*, sense of place, Stedman, 2003). Some residents, therefore, have affection for the beaver, or see it as a symbol of their own identity as settlers and colonists. This "adoption" of new biota, or in other words, the mechanism of co-producing identity or place meanings with biodiversity has been documented in European settlers in Australia, adopting, for example, native species to Australia that were "new" for these European colonists (Aslin and Bennett,

2000). In this context, local relationships with an invasive species are developed through direct experience, and therefore, these people may have high awareness of their impacts, but have a divergent valuation of the species itself and its management, compared to invasion biologists and conservationists. Indeed, it is reported in southern Patagonia that some social groups demonstrate reticence to support scientifically-determined control and eradication efforts (Schuettler *et al.*, 2011; Anderson *et al.*, 2016).

In agreement with these qualitative studies on Navarino Island, quantitative surveys administered on in Tierra del Fuego National Park found that while more than 90% of visitors who were residents of Ushuaia (Argentina) know the beaver is harmful, only approximately half support the total eradication via lethal means (Anderson *et al.*, 2016). This lack of support can be partially traced to underlying ethical frameworks (*e.g.*, anthropocentric versus biocentric worldviews) held by different stakeholders regarding nature and its management (Haider and Jax, 2007). Plus, we have found that even when there is support for invasive species removal, there can often be a general rejection of lethal control options, which allows us to distinguish that there is more support for the overall goal versus the

Figure 2. The beaver is most known for the large impacts that its tree cutting and dam-building provoke to the landscape **(a)**, but at the same time the species itself is often considered charismatic and interesting by many people **(b)**. Consequently, in Tierra del Fuego, this introduced invasive species is frequently used as a "mascot" for the town of Ushuaia in tourism promotional material **(c)** and even appears incorporated into the names of some private enterprises **(d)**. (Photos: J. C. Pizarro [**a**], J. Duncnuigeen [**b**], J. J. Henn [**c**], A. E. J. Valenzuela [**d**]).

means of achieving it (Anderson *et al.*, 2016). The same study also found that only half of residents can correctly identify native species on the island, but significantly more have knowledge of the presence of specific invasive taxa, of which the beaver is the best known (Anderson *et al.*, 2016).

Beavers are also charismatic mammals with conspicuous affects to both the ecological and aesthetic landscape (Fig. 2a-b). They create an ideal narrative and novelty for animal-based tourism (Bertella, 2016), and although this aspect has not been well-studied in Patagonia, tourism operators have incorporated beavers into their offering and local narrative (Fig. 2c-d). Ushuaia, for example, is a top destination for nature-based, international tourism, and beavers have often been depicted as a city mascot, together with native species like the Magellan penguin, in tourism advertising materials and brochures. Even the name of a world-renowned ski resort on the island is *Cerro Castor* or "Beaver Mountain." In many ways, this invasive species has become part of the toponomy of Tierra del Fuego's "iconic" landscape and in some ways serves as part of its natural and social capital for tourism. Using travel blogs, tourists from North America visiting the area are confronted with the duality of the local promotion of beavers as a tourist attraction and their noticeable environmental effects they experience while hiking (*e.g.*, Henn, 2013; Russell, 2016). In this human-nature "co-production" it is also important to consider that the region's demography and economy have been dramatically changing in the last 60 years (*e.g.*, van Aert, 2013), particularly for the Argentine portion. The massive immigration to the island in the last 30 years as part of industrial promotion incentives means that for many residents the beaver and its effects are perceived as entirely normal in Tierra del Fuego.

Despite these emerging studies, we know little about the role that people take in direct actions towards invasive species. Stakeholders have been shown to have a disparity between knowledge (*i.e.*, beavers produce environmental damage) and perception (*i.e.*, beavers are part of my place), but how these people act to confront invasive species has been little considered. Willingness-to-pay, while not action *per se*, provides some indications of people's intentions towards future behavior. For example, in Chile, a government-supported beaver control program promoted significant economic incentives for the trapping of beaver, American mink (*Neogale vison*) and muskrat (*Ondatra zibethicus*), but despite these efforts, neither a fur industry nor trapping were sparked and only few self-sustaining enterprises remain today (Soto and Cabello, 2007). In contrast, between 2011–2012, a destructive wildfire impacted Torito Bay north of Ushuaia. The perceived environmental damage and danger in this case lead citizens to self-organize a social-environmental movement in defense of the native forest. This social group pressed the authorities to integrate a broader array of stakeholders into the existing native forest advisory council (Comisión Consultiva de Bosques Nativos) and implement the provincial native forestry law to improve overall management, planning and conservation (Vara and Collado, 2013). We present these two contrasting examples of social responses that were exogenous versus endogenous and ultimately having differing outcomes and sustainability. Clearly, there is not the same motivation to act on the part of the local population despite the noticeable environmental effects of invasive beavers, and as previously stated, most of these issues described in this section have not yet been empirically researched or tested.

Lessons from the invasive beaver case study

Build a transdisciplinary invasive species research agenda

Transdisciplinarity is a practice and a property that emerges when a diverse group, including social actors beyond academia, works together to analyze a complex system via the "differentiation" and "reintegration" of the system's sub-components in an iterative process (similar to interdisciplinarity, see García, 2006; but expanding beyond academia, see Star and Griesemer, 1989). In this sense, the principal lesson of the case study is the utility of a continual and iterative process of 1) understanding the study object/subject and 2) identifying and incorporating particular dimensions that have been unattended. As such, new synergies and discoveries can be found along the way that also relate to the interface of a socio-ecological phenomenon and generating mutual comprehension. If the binational agreement and its activities to confront beavers' invasion were effective bringing scientific, diplomatic and management agendas together, we propose that it would be relevant to think that repeating the same "successful" recipe of collaborative work can offer similar results in the study of other biological invasions as a social-ecological phenomenon. Specifically, mechanisms like transdisciplinary seminars and participatory workshops were useful for the modification of the agenda on beavers and similar strategies could be used elsewhere and for other problematic taxa (García-Diaz *et al.*, 2021).

We would also call attention to the emerging research topics we identified under the lens of "nature as co-production," including incorporation of introduced invasive species as social (*i.e.*, creation of research-management network), natural (nature-based tourism attraction) and cultural (place identity and belonging) capital. We show that immigration and social and demographic change can be useful factors to incorporate to the study of local cultural images of nature and invasive species (see also Dicenta, 2021). Other invasive species, such trout and salmon, could be equally interesting to explore under these perspectives. Plus, in other "southern" countries like Australia and New Zealand, we can find concrete examples of how these research topics have become increasingly important to the global literature on the socio-ecological impacts of biological invasions (see Estévez *et al.*, 2015) and informing land-use policy and decision-making (Klepeis *et al.*, 2009).

Strengthen communities of knowledge

Since the 2006 binational politico-scientific process on beaver control began, there is increasing interest in interdisciplinary, applied and social science approaches to this biological invasion. As such, a watershed moment in the way this problem was conceived, studied and confronted was the conformation of a working group that linked researchers and managers—known as "knowledge-policy communities" (*sensu* Díaz *et al.*, 2015). Now, the recent social sciences studies highlighted above demonstrate that the broadening of this set of stakeholders also diversifies the perceptions and knowledge about beavers that are involved in the process. Therefore, the integration of social science domains with ecological ones also implies the incorporation of stakeholders beyond the ecological science and natural resource management realms (Colvin *et al.*, 2016). Strengthening such communities of

knowledge, then, requires attending to the question of how research should inform and encourage participative approaches in invasive species management for future actions (Star and Griesemer, 1989).

Moreover, biological invasions can be also understood even more broadly as having teleconnections and telecouplings (*sensu* Liu *et al.*, 2015), which expands the potential social actors of these knowledge communities to a global scale. For example, the case of the beaver demonstrates such long-distance socio-ecological system linkages. The introduction itself brought a species from North to South America, but currently the sharing of experiences on control has included experts from the United States, Canada and New Zealand (Malmierca *et al.*, 2011). As such, these comparative relationships provide an opportunity for research, management and conservation to be informed by other knowledge-policy communities facing similar issues or sharing the same species, but outside of academia these types of linkages between long-distance partners are less common, particularly at the local government and community levels (Ogden *et al.*, 2013).

The challenges of creating communities of knowledge exist even for simply building interdisciplinary working groups within academia and include financial, structural and implementation barriers (Anderson *et al.*, 2015). By encompassing practitioners and other local community members (*i.e.*, transdisciplinary), a new set of concerns emerge, such as power asymmetries, legitimacy and equity (Barnaud and Van Paassen, 2013). However, these issues are inherent and unavoidable if we are to transition into a paradigm of research and management as socio-ecological systems. While this represents a significant challenge for the capacity of both invasion biologists and managers, it is clear that doing so would promote not only mutual understanding, but also increase the legitimacy of information and its applicability to practical solutions.

Include environmental history and philosophy in natural science education curricula

Ecologists dominate invasion biology, given the history of this field (see above), and ecologists and natural scientists more generally have been shown to have relatively poor training in the philosophy of science (Graham and Dayton, 2002; Estévez *et al.*, 2010). To move beyond the uncritical adoption of hegemonic paradigms and principles, it is necessary to have a solid training in the humanities, particularly history and philosophy (Eigenbrode *et al.*, 2007). Doing so will give a new generation of scientists and managers involved in the study and control of biological invasions a broader understanding not only of their work, but the science-society relationship and the relationship of their discipline with other social actors. Clearly, humans do not just impact nature, nor do they simply receive benefits from it. Rather, a "humans as co-participants" perspective makes explicit that they also create multiple natures (*e.g.*, "novel ecosystems," Hobbs *et al.* 2006; "anthromes," Ellis *et al.*, 2010). However, recognizing these multi-faceted aspects of the human-nature relationship requires us to acknowledge and take responsibility for the lenses through which we view the world and our work.

Despite its inherited disciplinary biases, though, we would argue that invasion biology is well positioned to help lead other ecologists and natural scientists bridge this gap, given the applied nature of the field and the clear expression of values and priorities that invasion

biologists and practitioners in Patagonia have expressed (Anderson and Valenzuela, 2014). However, there is still a need for an institutionalization of training that allows scientists and practitioners to construct their own conceptual frameworks, based on the problem, rather than an imposed and inherited disciplinary structure. Doing so also should help researchers and their students reconcile their own values and priorities, which recognize the imperative of applying their information to real world, viable solutions (Anderson and Valenzuela, 2014). Plus, taking the approach to interdisciplinarity presented by García (2006), we first must have a joint understanding of system components, which for ecologists and natural resource managers alike are traditionally "humans as drivers of change." However, by explicitly integrating a historical and philosophical perspective to this process, we are also obliged to incorporate social science understandings, such as the fact that "humans" can be differentiated into multiple social actors or stakeholders, including ranchers, scientists, local leaders and decision-makers from the local to the regional and the international levels.

Conclusions

The scientific and management attention that the beaver has received, based largely on studies that conceive of beavers as human-induced impacts to nature, make this biological invasion one of the most studied in Patagonia (Valenzuela *et al.*, 2014). The review of the research shows that both ecological and social inquiry can provide useful data and insights on the beaver's effects, the invasion processes and socio-cultural aspects regarding environmental management. At the same time, we also would like to acknowledge that the emphasis towards ecological impact studies achieved valuable outcomes, such as yielding a great deal of basic information on understudied aquatic and riparian ecosystems in southern Patagonia and permitting significant and sustained efforts to develop relationships between researchers and decision-makers, ultimately positioning this topic in the political agenda of both Argentina and Chile.

By analyzing the case of invasive beavers under the rubric of a socio-ecological phenomenon, we now find the need to explicitly recognize that a new study object or unit also requires updated conceptual models and methods (see Anderson *et al.*, 2021). In turn, this socio-ecological perspective also challenges conservation and restoration approaches that seek to maintain "natural" ecological conditions and allows scientists and practitioners instead to engage with the novel or socially-desirable conditions that recognize humans and nature together as a unit. Therefore, a greater understanding of the history and philosophy of our scientific and management paradigms should also teach us to have not only better comprehension of these disciplines' trajectories, but also greater humility of their (and our) limitations, thereby becoming better equipped to constantly search for improvements that allow us to be more effective. We should be encouraged, as well, by other successful hybrid disciplines that have played a role in helping to relate human behavior with environmental situations from other standpoints (*e.g.*, ecological economics, environmental psychology, environmental anthropology, political ecology: see Bennett *et al.*, 2016). These other fields further demonstrate that to comprehend and manage biological invasions as a socio-ecological phenomenon, natural scientists and conservation practitioners would be well-served

to develop a more nuanced understanding of human values, perceptions and motivations, including acknowledging how these factors vary over time, place, and within socio-cultural contexts (Paetzold *et al.*, 2010; DeFries *et al.*, 2012).While the transformation of invasion biology into a field of inquiry and action that effectively integrates humans and nature is a major challenge, we find evidence from the case of invasive beavers, as well as in the broader academic experience, that 1) the construction of a transdisciplinary research agenda with appropriate study units and research methods, 2) the consolidation of communities of knowledge and practice, and 3) the teaching of philosophy and history to natural scientists are three concrete tasks that can help advance this proposal.

Acknowledgements

CBA recognizes the grant support of ECO-Link (GEO1262148) and PIDUNTDF A 2 /16 (*Un abordaje socio-ecológico para mejorar el entendimiento y la gestión de las invasiones biológicas en la Patagonia austral*), which provided a platform and interdisciplinary team to develop these ideas. JCP was supported by a CONICET Postdoctoral Fellowship during the preparation of the manuscript.

References

Adams, C.C. 1940. Introductory note. *Ecological Monographs* 10: 309–310.

Aggestam, F. 2015. Framing the ecosystem concept through a longitudinal study of the developments in science and policy. *Conservation Biology* 29: 1052–1064.

Anderson, C.B. and Rosemond, A.D. 2007. Ecosystem engineering by invasive exotic beavers reduces in-stream diversity and enhances ecosystem function in Cape Horn, Chile. *Oecologia* 154: 141–153.

Anderson, C.B. and Rosemond, A.D. 2010. Beaver invasion alters terrestrial subsidies to subantarctic stream food webs. *Hydrobiologia* 652: 349–361.

Anderson, C.B. and Valenzuela, A.E.J. 2014. Do what I say, not what I do. Are we linking research and decision-making about invasive species in Patagonia? *Ecología Austral* 24: 193–202.

Anderson, C.B., Rozzi, R., Torres-Mura, J.C., McGehee, S.M., Sherriffs, M.F., Schüttler, E. and Rosemond, A.D. 2006a. Exotic vertebrate fauna in the remote and pristine sub-Antarctic Cape Horn Archipelago, Chile. *Biodiversity and Conservation* 15: 3295–3313.

Anderson, C.B., Griffith, C.R., Rosemond, A.D., Rozzi, R. and Dollenz, O. 2006b. The effects of invasive North American beavers on riparian vegetation communities in Cape Horn, Chile: do exotic beavers engineer differently in sub-Antarctic ecosystems? *Biological Conservation* 128: 467–474.

Anderson, C.B., Martínez Pastur, G., Lencinas, M.V., Wallem, P.K., Moorman, M.C. and Rosemond, A.D. 2009. Do introduced North American beavers *Castor canadensis* engineer differently in southern South America? An overview with implications for restoration. *Mammal Review* 39: 33–52.

Anderson, C.B., Lencinas, M.V., Valenzuela, A.E.J., Simononok, M.P., Wallem, P.K. and Martinez Pastur, G. 2014. Ecosystem engineering by an invasive species, the beaver, increases landscape-level ecosystem function but does not affect biodiversity in Tierra del Fuego's freshwater systems. *Diversity and Distributions* 20: 214–222.

Anderson, C.B., Pizarro, J.C., Estevez, R., Sapoznikow, A., Pauchard, A., Barbosa, O., Moreira-Muñoz, A. and Valenzuela, A.E.J. 2015. ¿Estamos avanzando hacía una socio-ecología? Reflexiones sobre la integración de las dimensiones «humanas» en la ecología en el sur de América. *Ecología Austral* 25: 263–272.

Anderson, C.B. Valenzuela, A.E.J., Van Aert, P., Malizia, M., Car, V. and Ader, N. 2016. [*Informe Final, proyecto PEININ «El Parque Nacional Tierra del Fuego como un sistema socio-ecológico»*, Universidad Nacional de Tierra del Fuego, Ushuaia, 16 pp, Unpublished.]

Anderson, C.B., Pizarro, J.C., Valenzuela, A.E.J., Ader, N., Ballari, S., Cabello Cabalín, J.L., Car, V., Dicenta, M., Nielsen, E.A., Roulier, C. and Van Aert, P. 2021. Reconceiving the biological invasion of North American beavers (*Castor canadensis*) in southern Patagonia as a socio-ecological problem: implications and opportunities for research and management. In: F. Jaksic and S.A. Castro (eds.), *Biological invasions in the South American Anthropocene: global causes and local impacts*, pp. 231–255. Springer, Cham.

Archibald, J., Anderson, C.B., Dicenta, M., Roulier, C., Slutz, K. and Nielsen, E.A. 2020. The relevance of social imaginaries to understand and manage biological invasions in southern Patagonia. *Biological Invasions* 22: 3307–3323.

Aslin, H.J. and Bennett, D.H. 2000. Wildlife and world views: Australian attitudes toward wildlife. *Human Dimensions of Wildlife* 5: 15–35.

Barnaud, C. and Van Paassen, A. 2013. Equity, power games, and legitimacy: dilemmas of participatory natural resource management. *Ecology and Society* 18: 21. doi: 10.5751/ES-05459-180221.

Bennett, N.J., Roth, R., Klain, S.C., Chan, K.M.A., Clark, D.A., Cullman, D., Epstein, G., Nelson, M.P., Stedman, R., Teel, T.L., Thomas, R.E.W., Wyborn, C., Curran, D., Greenberg, A., Sandlos, J. and Veríssimo, D. 2016. Mainstreaming the social sciences in conservation. *Conservation Biology* 31: 56–66.

Berghoefer, U., Rozzi, R., and Jax, K. 2008. Local versus global knowledge: diverse perspectives on nature in the Cape Horn Biosphere Reserve. *Environmental Ethics* 30: 273–294.

Berghoefer, U., Rozzi, R. and Jax, K. 2010. Many eyes on nature: diverse perspectives in the Cape Horn Biosphere Reserve and their relevance for conservation. *Ecology and Society* 15: 18. http://www.ecologyandsociety.org/vol15/iss1/art18.

Bertella, G. 2016. Experiencing nature in animal-based tourism. *Journal of Outdoor Recreation and Tourism* 14: 22–26.

Brown, J.H. and Sax, D.F. 2004. An essay on some topics concerning invasive species. *Austral Ecology* 29: 530–536.

Buijs, A., Elands, B. and Langers, F. 2009. No wilderness for immigrants: cultural differences in images of nature and landscape preferences. *Landscape and Urban Planning* 91: 113–123.

Cadotte, M. 2011. Darwin, Charles. In: D. Simberloff and M. Rejmanek (eds.), *Encyclopedia of biological invasions*, pp. 142–144. University of California Press, Berkeley.

Colvin, R.M., Witt, G.B. and Lacey, J. 2016. Approaches to identifying stakeholders in environmental management: insights from practitioners to go beyond the "usual suspects." *Land Use Policy* 52: 266–276.

Convention on Biological Diversity (CBD). 1992. United Nations. https://www.cbd.int/doc/legal/cbd-en.pdf. Accessed on 11 March 2017.

Crutzen, P.J. 2002. Geology of mankind: the Anthropocene. *Nature* 415: 23.

Davis, M.A., Chew, M.K., Hobbs, R.J., Lugo, A.E., Ewel, J.J., Vermeij, G.J., Brown, J.H., Rosenzweig, M.L., Gardener, M.R. and Carroll, S.P. 2011. Don't judge species on their origins. *Nature* 474: 153–154.

DeFries, R.S., Ellis, E.C., Chapin, F.S., Matson, P.A., Turner, B.L., Agrawal, A., Crutzen, P.J., Field, C., Gleick, P., Kareiva, P.M., Lambin, E., Liverman, D., Ostrom, E., Sanchez, P.A. and Syvitski, J. 2012. Planetary opportunities: a social contract for global change science to contribute to a sustainable future. *Bioscience* 62: 603–606.

de Vries, H.J.M. and Petersen, A.C. 2009. Conceptualizing sustainable development: an assessment methodology connecting values, knowledge, worldviews and scenarios. *Ecological Economics* 68: 1006–1019.

Descola, P. and Pálsson, G. 1996. *Nature and society. Anthropological perspectives*. 310 pp. Routledge, London.

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Brondizio, E., Chan, K.M.A., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, T.S., Asfaw, Z., Bartus, G., Brooks, A.L., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi,

K., Thomas, S., Verma, M., Yeo-Chang, Y. and Zlatanova, D. 2015. The IPBES Conceptual Framework—connecting nature and people. *Current Opinion in Environmental Sustainability* 14: 1–16.

Dicenta, M. 2021. White animals: racializing sheep and beavers in the Argentinian Tierra del Fuego. *Latin American and Caribbean Ethnic Studies*. doi: 10.1080/17442222.2021.2015140.

Eigenbrode, S.D., O'Rourke, M., Wulfhorst, J.D., Althoff, D.M., Goldberg, C.S., Merrill, K., Morse, W., Nielsen-Pincus, M., Stephens, J., Winowiecki, L. and Bosque-Pérez, N.A. 2007. Employing philosophical dialogue in collaborative science. *BioScience* 57: 55–64.

Ellis, E.C. and Ramankutty, N. 2008. Putting people in the map: anthropogenic biomes of the world. *Frontiers in Ecology and the Environment* 6: 439–447.

Ellis, E.C., Klein Goldewijk, K., Siebert, S., Lightman, D. and Ramankutty, N. 2010. Anthropogenic transformation of the biomes, 1700 to 2000. *Global Ecology and Biogeography* 19: 589–606.

Elton, C.S. 1958. *The ecology of invasions by animals and plants*, 181 pp. Methuen, London.

Estenssoro Saavedra, J.F. 2007. Antecedentes para una historia del debate político en torno al medio ambiente. *Revista Universum* 22: 92–111.

Estévez, R.A., Sotomayor, D.A., Poole, A.K. and Pizarro, J.C. 2010. Creating a new cadre of academics capable of integrating socio-ecological approach to conservation biology. *Revista Chilena de Historia Natural* 83: 17–25.

Estévez, R., Anderson, C.B., Pizarro, J.C. and Burgman, M. 2015. Clarifying values, risk perception and attitudes to resolve or avoid social conflicts in invasive species management. *Conservation Biology* 29: 19–30.

Ford, A. and Nigh, R. 2009. Origins of the Maya forest garden: Maya resource management. *Journal of Ethnobiology* 29: 213–236.

García, R. 2006. *Sistemas complejos: conceptos, método y fundamentación epistemológica de la investigación interdisciplinaria*. Ed. Gedisa, Barcelona, España, 202 pp.

García-Díaz, P., Cassey, P., Norbury, G., Lambin, X., Montti, L., Pizarro, J.C., Powell, P.A., Burslem, D.F.R.P., Cava, M., Damasceno, G., Fasola, L., Fidelis, A., Huerta, M.F., Langdon, B., Linardaki, E., Moyano J., Núñez, M.A., Pauchard, A., Phimister, E., Raffo, E., Roesler, I., Rodríguez-Jorquera, I., and Tomasevic, J.A. 2021. Management policies for invasive alien species: addressing the impacts rather than the species. *BioScience* 7: 174–185.

García-Quijano, C.G., Carlo, T.A. and Arce-Nazario, J. 2011. Human ecology of a species introduction: interactions between humans and introduced green iguanas in a Puerto Rican urban estuary. *Human Organization* 70: 164–178.

Gleason, H.A. 1926. The individualistic concept of the plant association. *The American Midland Naturalist* 21: 92–110.

Global Environment Facility (GEF). 2013. *Proyecto 83266: Fortalecimiento de los marcos nacionales para la gobernabilidad de las Especies Exóticas Invasoras*. https://gefcastor.mma.gob.cl.

Graham, M.H. and Dayton, P.K. 2002. On the evolution of ecological ideas: paradigms and scientific progress. *Ecology* 83: 1481–89.

Guichón, M.L., Borgnia, M., Benitez, V.V. and Gozzi, A.C. This volume. Charisma as a key attribute for the expansion and protection of squirrels introduced to Argentina, pp. 53–73.

Haider, S. and K. Jax. 2007. The application of environmental ethics in biological conservation: a case study from the southernmost tip of the Americas. *Biodiversity and Conservation* 16: 2559–2573.

Henn, J.J., Anderson, C.B. and Martinez Pastur, G. 2016. Landscape-level impact and habitat factors that explain invasive beaver distribution in Tierra del Fuego. *Biological Invasions* 18: 1679–1688.

Henn, J.J., Anderson, C.B., Kreps, G., Lencinas, M.V., Soler, R. and Martínez Pastur, G. 2014. Determining abiotic and biotic factors that limit transplanted *Nothofagus pumilio* seedling success in abandoned beaver meadows in Tierra del Fuego. *Ecological Restoration* 32: 369–378.

Henn, J.J. 2013. History lesson #1: beaver invasion of Tierra del Fuego. *Jon Henn's Website*. https://jonsadventure.wordpress.com/2013/02/07/history-lesson-1-beaver-invasion-of-tierra-del-fuego. Accessed on 17 March 2017.

Hinchliffe, S. 2007. *Geographies of Nature: societies, environments, ecologies*. First edition, 224 pp. Sage Publications Ltd., London, UK.

Hobbs, R.J., Arico, S., Aronson, J., Baron, J.S., Bridgewater, P., Cramer, V., Epstein, P.R., Ewel, J.J., Klink, C.A., Lugo, A.E., Norton, D., Ojima, D., Richardson, D.M., Sanderson, E.W., Valladares, F., Vilá, M., Zamora, R. and Martin, Z. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* 15: 1–7.

Huenneke, L., Glick, D., Waweru, F.W., Brownell Jr., R.L. and Goodland, R. 1988. SCOPE Program on Biological Invasions: a status report. *Conservation Biology* 2: 8–10.

Ingold, T. 2000. *The perception of the environment*, 480 pp. Routledge, London, UK.

International Union for Conservation of Nature (IUCN). 2017. *Invasive alien species*. https://www.iucn.org/our-work/topic/invasive-alien-species. Accessed on 20 February 2022.

Jones, C.G., Lawton, J.H. and Shachak, M. 1994. Organisms as ecosystem engineers. *Oikos* 69: 373–386.

Kareiva, P., Watts, S., McDonald, R. and Boucher, T. 2007. Domesticated nature: shaping landscapes and ecosystems for human welfare. *Science* 316: 1866–1869.

Kareiva, P., Marvier, M. and Lalasz, R. 2012. Conservation in the Anthropocene: beyond solitude and fragility. *Breakthrough Journal* 2. https://thebreakthrough.org/journal/issue-2/conservation-in-the-anthropocene.

Klepeis, P., Gill, N. and Chisholm, L. 2009. Emerging amenity landscapes: invasive weeds and land subdivision in rural Australia. *Land Use Policy* 26: 380–392.

Larson, B.M.H. 2005. The war of the roses: demilitarizing invasion biology. *Frontiers in Ecology and the Environment* 3: 495–500.

Liu, J., Hull, V., Luo, J., Yang, W., Liu, W., Viña, A., Vogt, C., Xu, Z., Yang, H., Zhang, J., An, L., Chen, X., Li, S., Ouyang, Z., Xu, W. and Zhang, H. 2015. Multiple telecouplings and their complex interrelationships. *Ecology and Society* 20(3): 44.

Lizarralde, M. 1993. Current status of the introduced beaver (*Castor canadensis*) population in Tierra del Fuego, Argentina. *Ambio* 22: 351–358.

Mace, G.M. 2014. Whose conservation? *Science* 345: 1558–1560.

MacIntosh, R. 1985. *The background of Ecology: concept and theory*, 383 pp. Cambridge University Press. New York, NY.

Mackenzie, B.F. and Larson, B.M.H. 2010. Participation under time constraints: landowner perceptions of rapid response to the emerald ash borer. *Society and Natural Resources* 23: 1013–1022.

Malmierca, L., Menvielle, M.F., Ramadori, D., Saavedra, B., Saunders, A., Soto, N. and Schiavini, A. 2011. Eradication of beaver (*Castor canadensis*), an ecosystem engineer and threat to southern Patagonia. In: C. Veitch, M. Clout and D. Towns (eds.), *Island invasives: eradication and management*, pp. 87–90. IUCN, Gland, Switzerland.

McKinney, M.L. and Lockwood, J.L. 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. *Trends in Ecology & Evolution* 14: 450–453.

Meine, C., Soulé, M. and Noss, R. 2010. A mission-driven discipline: the growth of conservation biology. *Conservation Biology* 20: 631–651.

Menvielle, M.F., Funes, M., Malmierca, L., Ramadori, D., Saavedra, B., Schiavini, A. and Soto Volkart, N. 2010. American beaver eradication in the southern tip of South America: main challenges of an ambitious project. *Aliens: the Invasive Species Bulletin* 29: 9–16.

Ministerio de Relaciones Exteriores–Chile. 2008. http://anfitrion.cl/GobiernoTransparente/minrel/NG/DCTO/2008/12/28681.html. Accessed on 11 March 2017.

Norgaard, R.B. 2010. Ecosystem services: from eye-opening metaphor to complexity blinder. *Ecological Economics* 69: 1219–1227

Odum, E.P. 1953. *Fundamentals of Ecology*, 546 pp. Second edition. Ed. W.B. Saunders, Philadelphia.

Ogden, L., Heynen, N., Oslender, U., West, P., Kassam, K.-A. and Robbins, P. 2013. Global assemblages, resilience, and earth stewardship in the Anthropocene. *Frontiers in Ecology and the Environment* 11: 341–347.

Ogden, L.A. and Holmes, G. 2015. Involucramientos globales del bosque, incluso en el fin del mundo. In: M. Prieto, B. Bustos and J. Barton (eds.), *Ecología política en Chile: naturaleza, conocimiento, poder y propiedad*, pp. 64–88. Universidad de Chile, Editorial Universitaria, Santiago de Chile.

Paetzold, A., Warren, P.H. and Maltby, L.L. 2010. A framework for assessing ecological quality based on ecosystem services. *Ecological Complexity* 7: 273–281.

Paini, D.R., Sheppard, A.W., Cook, D.C., De Barro, P.J., Worner, S.P. and Thomas, M.B. 2016. Global threat to agriculture from invasive species. *Proceedings of the National Academy of Sciences* 113: 7575–7579.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R., BasakDessane, E., Islar, M., Keleman, E., Maris, V., Quaas, M., Subramanian, S.M., Wittmer, H., Adlan, A., Ahn, S.E., Al-Hafedh, Y.S., Amankwah, E., Asah, S.T., Berry, P., Bilgin, A., Breslow, S.J., Bullock, C., Cáceres, D., Daly-Hassen, H., Figueroa, E., Golden, C.D., Gómez-Baggethun, E., González-Jiménez, D., Houdet, J., Heune, H., Kumar, R., Ma, K., May, P.H., Mead, A., O'Farrell, P., Pandit, R., Pengue, W., Pichis-Madruga, R., Popa, F., Preston, S., Pacheco-Balanza, D., Saarikoski, H., Strassburg, B.B., van den Belt, M., Verma, M., Wickson, F. and Yagi, N. 2017. Valuing nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability* 26–27: 7–16.

Pauchard, A., Quiroz, C.L., García, R., Anderson, C.B., and Kalin, M.T. 2011. Invasiones biológicas en América Latina y el Caribe: tendencias en investigación para la conservación. In: J.A. Simonetti and R. Dirzo (eds.), *Conservación biológica: perspectivas desde América Latina*, pp. 79–94. Editorial Universitaria, Santiago, Chile.

Pfeiffer, J.M. and Voeks, R.A. 2008. Biological invasions and biocultural diversity: linking ecological and cultural systems. *Environmental Conservation* 35: 281–293.

Pickett, S.T.A. and Ostfeld, R.S. 1995. The shifting paradigm in ecology. In: R.L. Knight and S.F. Bates (eds.), *A new century for natural resources management*, pp. 261–278. Island Press, Washington, DC.

Pretty, J. 2011. Interdisciplinary progress in approaches to address social-ecological and ecocultural systems. *Environmental Conservation* 38: 127–139.

Pysek, P., Richardson, D.M. and Jarosík, V. 2006. Who cites who in the invasion zoo: insights from an analysis of the most highly cited papers in invasion ecology. *Preslia* 78: 437–468.

Quiroz, C.L., Pauchard, A., Cavieres, L.A. and Anderson, C.B. 2006. Investigación en invasiones biológicas en Chile: tendencias y desafíos. *Revista Chilena de Historia Natural* 82: 497–505.

Russell, J. 2016. Chasing beaver at the End of the World. Water Currents. *National Geographic Online*. http://voices.nationalgeographic.com/2016/01/31/chasing-beaver-at-the-end-of-the-world. Accessed on 17 March 2017.

Santo, A.R., Sorice, M.G., Donlan, C.J., Franck, C.T. and Anderson, C.B. 2015. A human-centered approach to designing invasive species eradication programs on human-inhabited islands. *Global Environmental Change* 35: 289–298.

Santo, A.R., Guillozet, K., Sorice, M.G., Baird, T.D., Gray, S., Donlan, C.J. and Anderson, C.B. 2017. Examining private landowners' knowledge systems of an invasive species. *Human Ecology* 45: 449–462.

Schuettler, E., Rozzi, R. and Jax, K. 2011. Towards a societal discourse on invasive species management: a case study of public perceptions of mink and beavers in Cape Horn. *Journal for Nature Conservation* 19: 175–184.

Sconnes, I. 1999. New ecology and the social sciences: what prospects for a fruitful engagement? *Annual Review of Anthropology* 28: 479–507.

Scorolli, A.L. This volume. Management of feral horses as invasive mammals: biodiversity conservation versus culture? pp. 111–126.

Simberloff, D. *et al.* 2011. Non-natives: 141 scientists object. *Nature* 475: 36.

Skewes, O., González, F., Olave, R., Ávila, A., Vargas, V., Paulsen, P. and König, H. 2006. Abundance and distribution of American beaver, *Castor canadensis* (Kuhl, 1820), in Tierra del Fuego and Navarino Islands, Chile. *European Journal of Wildlife Research* 52: 292–296.

Sorice, M. and Donlan, C.J. 2015. A human-centered framework for innovation in conservation incentive programs. *Ambio* 44: 788–792.

Soto, N. and Cabello, J.L. 2007. [*Informe Final. Programa Control de Fauna Dañina en la XII[a] Región*. SAG FONDEMA 2004–2007, Punta Arenas, 45 pp. Unpublished.]

Soto Simeone, A. and Soza-Amigo, S. 2014. Valoración económica del bosque nativo afectado por la introducción del castor americano en Tierra del Fuego. *Bosque* 35: 229–234.

Star, S.L. and Griesemer, J.R. 1989. Institutional ecology, "translations" and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. *Social Studies of Science* 19: 387–420.

Stedman, R.C. 2003. Is it really just a social construction?: the contribution of the physical environment to sense of place. *Society and Natural Resources* 16: 671–685.

Valenzuela, A.E.J., Anderson, C.B., Fasola, L. and Cabello, J.L. 2014. Linking invasive exotic species and their ecosystem impacts in Tierra del Fuego to test theory and determine action. *Acta Oecologica* 54: 110–118.

van Aert, P. 2013. Tierra del Fuego. In: G. Baldacchino (ed.), *Political economy of divided islands*, pp. 195–208. Palgrave MacMillan, Hampshire, UK..

Vara, P. and Collado, L. 2013. [Hacia la implementación de políticas de protección ambiental de los Bosques Nativos. Un análisis del proceso de diálogo iniciado entre el 2008–2012 para el ordenamiento de los bosques de la provincia de Tierra del Fuego. *XI Congreso Nacional de Ciencia Política*. Sociedad Argentina de Análisis Político y Universidad Nacional de Entre Ríos, Paraná, 23 pp. Unpublished.]

Vertovec, S. 2007. Super-diversity and its implications. *Ethnic and Racial Studies* 30: 1024–1054.

Vitousek, P.M., Mooney, H.A., Lubchenco, J. and Melillo, J.M. 1997. Introduced species: a significant component of human-caused global change. *New Zealand Journal of Ecology* 21: 1–16.

Wallem, P.K., Anderson, C.B., Martínez-Pastur, G. and Lencinas, M.V. 2010. Using assembly rules to measure the resilience of riparian plant communities to beaver invasion in subantarctic forests. *Biological Invasions* 12: 325–335.

Wallem, P.K., Jones, C.G., Marquet, P.A. and Jaksic, F.M. 2007. Identificación de los mecanismos subyacentes a la invasión de *Castor canadensis* (Rodentia) en el archipiélago de Tierra del Fuego, Chile. *Revista Chilena de Historia Natural* 80: 309–325.

Williamson, M. 1996. *Biological Invasions*, pp. 244, Springer, New York, NY.

Woods, M. and Moriarity, P.V. 2001. Strangers in a strange land: the problem of exotic species. *Environmental Values* 10: 163–191.

SAREM Series A | Mammalogical Research
Investigaciones Mastozoológicas

INTRODUCED INVASIVE MAMMALS OF ARGENTINA

Introduced Invasive Mammals (IIMs) are a major driver of global and local environmental change, including negative impacts on biodiversity, ecosystem processes, economies, health and other social values. However, as complex social-ecological systems, invasive species cannot be conceived solely as "negative," nor merely as "biological" invasions. This book presents conceptual and practical perspectives from 49 authors with expertise in communication, ecology, education, genetics, history, philosophy, social sciences and veterinary medicine to better understand and manage IIMs in Argentina. It concludes by providing updated information on Argentina's IIM assemblage, which includes 23 species.

Alejandro E. J. Valenzuela, **Christopher B. Anderson**, **Sebastián A. Ballari** and **Ricardo A. Ojeda**, EDITORS

SAREM Series A
Mammalogical Research
Investigaciones Mastozoológicas

ISBN 978-987-98497-9-8