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Rodolfo Gentili, Urs Schaffner, Adriano Martinoli & Sandra Citterio

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Invasive alien species and biodiversity: impacts and management

As far back as the 18th century, many naturalists including Augustin Pyramus De Candolle and Charles Darwin, observed the phenomenon of non-native species. These were defined as 'species outside of their bioregion which can possibly threaten native ones (De Candolle 1855; Darwin 1859; Pyšek et al. 2004). It was however only after the 1950s that scientists became aware that biological invasions can have a deleterious effect on habitats and ecosystems (Elton 1958; Macdonald and Jarman 1984; Davis 2009). The 'father' of invasion biology, Charles Elton, defined biological invasions as 'ecological explosions' meaning 'the enormous increase in number of some organism' in newly invaded ranges (Elton 1958). A combination of colonial rule, rapid economic development and increasing global trade exchanges across continents and borders have had a key role in human-mediated movement of propagules and species and have led to the subsequent establishment of non-native species in new regions outside their natural range (Turbelin et al. 2017). Indeed, the number of new recordings of invasive alien species (IAS) have incessantly increased worldwide during the last 200 years, but more than a third of all first introductions were recorded between 1970 and 2014 (Seebens et al. 2017). Over the last 30 years, numerous studies have demonstrated the negative effect of IAS on native biodiversity from the genetic (e.g. interspecific hybridization) to the ecosystem and landscape level (Largiadèr 2008; Kumschick et al. 2015; Lazzaro et al. 2020; Viciani et al. 2020). Today, biological invasions are considered among the main drivers causing biodiversity loss and species extinctions in the major plant and animal taxa across the world (IUCN 2017; Dueñas et al. 2021). Particularly, according to Bellard et al. (2016), IAS are the second most frequent threat connected with species' extinction events since 1500. Besides biodiversity loss, the most recent literature on IAS has pointed out that these species have negative impacts on agriculture, ecosystem services and human well-being (including human health), ultimately causing serious economic problems (Pejchar and Mooney 2009; McGeoch et al. 2010; Paini et al. 2016). Economic damages due to IAS should include costs related to the direct damage caused by the species as well as those to be ascribed to their prevention, control and management (Marbua et al. 2014).

Even though environmental issues caused by IAS are recognized worldwide, knowledge on their current and future impacts on native biodiversity is still largely unknown (Downey and Richardson 2016; Essl et al. 2020). Numerous IAS can colonize, with different strengths, ecosystems in different bioregions of the world; whilst on the other hand, biological invasions are a continuous phenomenon and so far only observed for too short a period (i.e. mainly over the last century) to really understand the response of the native species assemblages and ecosystems. Yet, the management of the most invasive alien species is still challenging or an unsolved problem all over the world.

For precisely these reasons, at *Biodiversity* journal, we felt it was high time we curated a themed issue, sharing examples from around the globe, on *Invasive Alien Species and Biodiversity: Impacts and Management*. Throughout, we have tried to provide new insights into such an important, and yet still under-studied area of research and scientific practice. In *The spread of exotic fishes in the Italian rivers and their effect on native fish fauna during the last three decades* the authors analysed 30-years of data recording (1985–2014) of fishes in Italy (BioFresh Project) with the aim to investigate the effects of introduced alien fish species on native species. The results showed that the richness of alien species is still increasing in Italy, while native species are decreasing. In addition, the invasion of the rivers in the Continental and Mediterranean biogeographic regions of Italy has induced more changes at the community level than the invasion of rivers in the Alpine region.

Knowledge around IAS in the marine environment is still scarce. The synthesis *Marine alien species: a challenge to biodiversity conservation in Marine Protected Areas. The case study of the Egadi Islands MPA (Tyrrhenian Sea, Italy)* provides an insight into the management of IAS across Marine Protected Areas of the Mediterranean region describing the spread dynamics and future trends of non-indigenous organisms.

Potential risks of invasive alien plant species on native plant biodiversity in Sri Lanka under climate change, Champika investigates the implications of the potential distribution of plant invasions on native biodiversity under climate change using a species' modelling approach. Biodiversity-rich zones are at potentially

high-risk of invasion under climate change. The potential risk on threatened endemic plants is expected to reduce under a RCP 4.5 low-emissions scenario and to be higher under RCP 8.5 high-emissions scenario.

Lockdown policy effects on invasive species: a perspective provides us with an overview on how the recent COVID-19 pandemic has impacted environmental policies around the management of IAS, protected actions, etc., and the research activities on IAS, which in turn, have partially changed their behaviour.

Diversity and abundance of soil-litter arthropods and their relationships with soil physicochemical properties under different land uses in Rwanda explores the relationships between families of soil-litter arthropods and soil properties under exotic and native tree species as well as in tree plantations. The authors finding were fascinating: revealing that forests with native tree species play an important role in the conservation of soil-litter arthropods and for maintenance of better soil conditions.

Impact of Acacia saligna on Composition and Structure of Mediterranean Maquis evaluates the ecological impacts of the IAS *Acacia saligna* on vegetation composition and structure of two coastal dune habitats (i.e., sclerophyllous vegetation and *Juniperus* scrubs). The invasion of *A. saligna* induced a decrease of native species cover, increase of ruderals and alien species, and changed the vegetation structure.

Effects of Invasive Alien Plants on riparian vegetation over a 20-year time-lapse: a case study of the Alviano Lake in the Tiber river (Umbria-Central Italy) reports on the effect of the invasion of two alien species on the riparian vegetation of an Italian River, studied over a 20-years period. The marked changes observed in the riparian vegetation composition and structure highlights how IAS can deeply modify landscapes and displace native species and communities. It is therefore essential that more awareness is crated around IAS and their impacts.

Finally, our *On the Ground* pieces offer – as the name suggests – how IAS play out on the ground and in a practical application. *Applying competition theory for the ecological restoration of communities to prevent plant invasions* discusses the use of three key hypotheses in invasion science, (diversity-invasibility, limiting similarity and Darwin's naturalization hypotheses) with the aim to better address community-based restoration.

Using local hay seed for suppressing invasive alien plants in grasslands reports on the use of local plant material for controlling alien species and promotes the use of hay seed collected from biodiverse grasslands.

A Golden Cage for the European red squirrel in Italy? discusses which management strategy is the most appropriate to control red squirrel invasion in Europe. Both intervention to eradicate populations and long-

term control strategies aiming at limiting the expansion of the species are proposed.

Finally, *Some like it fishless: the reasons and potential for eradicating alien fish from European mountain lakes* discusses about the ecological costs of the lack of management measures to eradicate invasive fishes from European mountain lakes and the reasons for embracing a conservation-minded approach to the management of fish resources in mountain areas.

In conclusion, we believe that all the new data of this special issue such as temporal trends after invasion events, impacts on native diversity (from species to communities) as well the new point of views will increase the knowledge and awareness about the IAS and may support new ideas on how to consider and manage them. Management actions applied in current and future times to control IAS must take into account that natural ecosystems are going to face substantial, fast and in some case permanent changes due to key environmental drivers such as climate change, nitrogen deposition, habitat loss, land-use changes, and microplastic pollution. In this scenario, new holistic challenging approaches to safeguard biodiversity will be needed.

Notes on contributors

Rodolfo Gentili is a researcher based in Milan. He has a keen interest in research concerning alien species control using competitive vegetation and restoration of degraded environments.

Urs Schaffner is Head of the Ecosystem Management Section at CABI in Switzerland and has been working for more than 25 years on biological invasions, biological control and the conservation and restoration of grasslands.

Adriano Martinoli is a researcher based in Varese. His research focuses in particular on the impact of alien mammals on native species and on the functioning of ecosystems.

Sandra Citterio is Professor of Plant Sciences at the University of Milano-Bicocca. She is interested in the impacts of alien plants on ecosystems and human health.

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Rodolfo Gentili

Università degli Studi di Milano-Bicocca

 rodolfo.gentili@unimib.it

Urs Schaffner

CABI International, Switzerland

Adriano Martinoli

Università degli Studi dell'Insubria

Sandra Citterio

Università degli Studi di Milano-Bicocca