Preface

BIOLOGICAL INVADERS IN INLAND WATERS: PROFILES, DISTRIBUTION, AND THREATS

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FRANCESCA GHERARDI

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Foreword

Q: Why are some environments more vulnerable to invasion than others?
A: Environments? In the first volume of this series you asked which species traits coincide with good invaders . . . now environments!
Q: Sure, if traits are not terribly powerful predictors alone, I thought that perhaps species traits and kinds of systems might somehow covary. What do you think?
A: Well that depends.
Q: Depends on what?
A: That depends too.

Freshwater environments are islands of sorts. Lakes, rivers, streams and wetlands are uniquely bounded and discrete at one readily apparent scale of observation, the basin or channel boundary. It comes as no surprise, then, that ecological thought has been so strongly influenced by research conducted within the confines of systems so easily circumscribed. Yet, aquatic and terrestrial habitats are inexorably coupled such that this boundary, while substantial at some scales or levels of organization, vanishes at others. This fact is well illustrated by the cascading or indirect effects induced by non-native species that readily traverse the interface between land and water.

Biological invasions represent the latest threat to the integrity of freshwater ecosystems worldwide, systems that are already impacted in massive fashion by human activity. Based on the number of documented and potential extinctions, the freshwater fauna of North America are experiencing an extinction rate that is five times that of the terrestrial environment.[i] While unrelenting habitat modification and resource exploitation directly accounts for many of these species losses, exotic species have surely played a role in what is an unprecedented

[i] Ricciardi, A. and J.B. Rasmussen. 1998. Extinction rates of North American Freshwater Fauna. Conserv. Biol. 13: 1220–1222.

episode of extinction in real time. Humans, however, are not safe in their role as the dominant purveyors of extinction. Ecosystem modification is often accompanied by increased susceptibility to invasion, and once established, exotic species are fully capable of changing all the rules driving system organization.

This is a broad-based volume, crafted with the widest possible brush strokes. Francesca Gherardi set out to create a volume that not only addressed the phenomenon of biological invasions in freshwater systems, but that also reflects the very breadth of contemporary approaches employed to understand the threats posed by the global movement of species. Here, the reader will find specificity and generality, application as well as theory, along with the sociopolitical implications and response to a global crisis. In a very real sense, this volume represents *everything invasions*.

James Drake
Series Editor

Preface

Nowadays we live in a very explosive world, and while we may not know where or when the next outburst will be, we might hope to find ways of stopping it or at any rate damping down its force.

Charles Elton 1958

In the past few decades, it has become clear to scientists and policy-makers that the human-mediated introduction of species – meaning the deliberate or accidental introduction into the wild of microbes, fungi, plants, and animals, including genetically modified organisms (GMOs) outside their natural range of distribution – is the main driver of biodiversity change (Sala *et al*. 2000). Acting often in concert with other anthropogenic alterations to the environment, such as changes in land use, climate, nitrogen deposition, and atmospheric CO_2, the effects on global biodiversity are expected to increase quickly with time in both extent and intensity.

Changes in the natural distribution of species should not, in general, be viewed as abnormal events (Lodge 1993). They are commonplace in nature, often occurring over the course of geological times in association with climate change (Graumlich and Davis 1993). But only rare events, usually associated with unusual climatic conditions such as storms, may induce the dispersal of species to habitats previously beyond their natural dispersal capabilities (MacIsaac *et al*. 2001). Human actions are more frequent and powerful. Such actions have greatly increased the temporal rate at which species disperse and the distances they traverse, accomplishing in a few decades something that could have never been accomplished by the means of natural events alone (Lodge 1993).

Since their earliest migrations, humans have contributed to the spread of organisms, always carrying them and their propagules over long distances. But the frequency of human-induced introductions of species and the consequent risks associated with them have augmented exponentially in the recent past in concert with the fast growth of the human population and with the rapid escalation of our potentials to alter the environment. Large numbers of people are today traveling faster and farther, and more and more goods and materials are being traded among nations and continents (Pimentel *et al.* 2002), creating a ''New Pangaea'' (Mooney 1998 cited by Rosenzweig 2001). All these factors combined have produced burgeoning rates of non-indigenous species (NIS) in every ecosystem that has been monitored. Over 480,000 NIS have been introduced into the varied ecosystems on earth (Pimentel *et al.* 2002) and have come to dominate about 3% of the ice-free surface over the last 500 years (Mack 1985). Their prevalence is exacerbated by climatic changes that in their turn favor the natural spread and proliferation of NIS (Dukes and Mooney 1999, Carlton 2000, Cowx 2002). The combined effect of the spread of cosmopolitan species and the extinction or range contraction of regional and endemic indigenous organisms often results in the ''mingling'' of the taxonomic composition of once disparate biota (Olden *et al.* 2004). This phenomenon is inevitably leading to the ''homogenization'' (McKinney and Lockwood 1999) or ''McDonaldization'' of the biosphere (Lövei 1997) that will characterize, it has been said, the forthcoming ''Homogocene'' era (Orians 1994 cited by Rosenzweig 2001).

Indeed, several introduced species have been beneficial to humans; species such as corn, wheat, rice, plantation forests, domestic chicken, cattle, and others provide now more than 98% of the world's food supply (Ewel *et al.* 1999, Pimentel *et al.* 2002). Many cause minimal environmental impact, as predicted by the oft-cited ''tens rule'' (Williamson and Fitter 1996). So, the fraction of the introduced species that cause problems is small, but their impact could be very serious. These species have the potential of becoming numerically and ecologically prominent; they spread from the point of introduction and are often able to dominate indigenous populations and communities (Kolar and Lodge 2001); they may profoundly and adversely affect indigenous species, ecosystem processes, economic interests, and public health (e.g. Ricciardi *et al.* 1998). In sum, they may turn out to be invasive. Their effects that justify alarm include biodiversity loss at the level of species, large reduction in the lower (genetic) and higher (generic) levels of biodiversity, changes in ecosystem functions, alteration of the ecosystem services provided to humans, aesthetic modifications of landscapes, direct costs to industries, damage to crops and forests, and the spread of human diseases, such as HIV and West Nile virus (Mack *et al.* 2000). Also, deliberate introductions made to solve local or regional problems may be responsible for serious ecological and economic consequences, the so-called Frankenstein Effect (Moyle *et al.* 1986). The costs they inflict form a hidden but onerous ''tax'' on many goods and services and the damages they cause are often irrevocable: biological invaders act as biological pollutants that, unlike chemicals, reproduce and spread autonomously, over great distances, and can adapt to changing conditions. Their impacts may be continuously increasing over time, even when their introduction ceases.

Since the 1980s, studies of NIS have expanded greatly, resulting in a flood of scientific publications and in the foundation of two invasion-focused journals, *Diversity and Distribution* (Blackwell Publishing) in 1998 and *Biological Invasions* (Kluwer-Springer) in 1999, this growth reflecting the rise in popularity that the discipline of invasion biology has gained as an appealing area of research among ecologists. The overall number of published articles appears, however, to be significantly biased towards terrestrial invaders; invasive events occurring in freshwater systems have been most often neglected or analyzed in a few regional contexts or for a small number of paradigmatic species.

In this book, the identity, distribution, and impact of freshwater NIS will be examined, as well as the dynamics of their invasion. Rather than providing a broad and comprehensive review of the issue, *Biological Invaders in Inland Waters* focuses on old and new invaders and also raises questions and opens perspectives that will be of stimulus for further research. Inland waters will be taken here as meaning rivers, lakes, and reservoirs. Coastal lagoons, saline lakes, estuaries, and low salinity seas such as the Baltic, will be mentioned when appropriate.

The ultimate, ambitious purpose of the book is to help define a more general framework for our knowledge of invasions in fresh waters. Such a framework will be indispensable to the planning of a science-based management program. Inspiration for this effort came from the International Workshop, ‘‘Biological Invasions in Inland Waters’’ (INWAT), held in Florence (Italy) between 5 and 7 May 2005 and made possible by support from Ente Cassa di Risparmio di Firenze, the Italian Ministry of University and Scientific Research (MIUR), the University of Florence, the Provinces of Arezzo, Firenze, Grosseto, Pisa, and Pistoia, and the International Association of Astacology. The INWAT Workshop was a necessary addendum of the final meeting (Florence, 2–5 May 2005) of the European network CRAYNET (‘‘European crayfish as keystone species – linking science, management and economics with sustainable environmental quality’’, coordinator Catherine Souty-Grosset) (Fifth EU Framework).

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