PREFACE

Alien—also called non-indigenous or non-native—species are defined as those species that colonize an area beyond their natural range, where they reproduce and establish a population. It is known that plants, animals and microorganisms have been intentionally transferred with human discovery voyages for centuries and, possibly, since the shift from foraging to agricultural and pastoralist societies. As a result, many 'exotic' species are now among our preferred foods, dearest pets, good-looking houseplants and decorative aquarium weeds, but most of them cannot be considered alien species, as they grow well only in artificially-controlled conditions or in protected environments. Conversely, alien species are capable of ready acclimation to novel habitats, where they may find themselves unconstrained by the limiting factors—both abiotic and biotic—typical of their original habitat. In these 'favorable' conditions, they might outgrow, and ultimately overthrow, resident organisms with which they happen to compete: in this case, alien species are often dubbed 'invasive'. This book discusses patterns, management and economic impact of these biological invasions.

Chapter 1 – Alien species, defined as those species that are introduced to an area outside their natural range, are recognized as a major threat to the conservation of biodiversity and functioning of marine ecosystems. Coastal marine habitats are among the most heavily invaded systems on earth, which is derived, in part, by human-mediated transport of potentially invasive species in ships' ballast as well as intentional introductions for aquaculture and fisheries enhancement. Transfers of cultured fish and shellfish are also responsible for the accidental introduction of 'hitch-hiking' species, which could become invasive and severely affect the recipient ecosystem. In addition, man-induced climate change and eutrophication are expected to increase the susceptibility of ecosystems to invasion by alien species.

Although microorganisms are by far the most abundant and diverse of aquatic life forms, research on microbial alien species introductions has lagged behind that on metazoans and macroalgae. It is now evident, however, that due to human activities, thousands of species of marine viruses, prokaryotes and protists are being transported within and between oceans, irrespective of any natural barriers. Because of their metabolic plasticity, short generation times, wide tolerance to environmental conditions, and ability to form resting stages, microorganisms are likely the most successful invaders of coastal ecosystems.

It is well known that invasive microalgae capable of forming massive blooms can cause economic losses to aquaculture, fisheries and tourism activities and have important environmental and human health impacts. There is also growing evidence that, besides free-living species, pathogens and parasites are being frequently introduced into coastal systems, with potentially enormous consequences for economic activities and human health. Regulations at national and above-national levels are thus being implemented to face these emergent issues.

Chapter 2 – In last centuries, many bird species have been introduced worldwide. Some of these bird species have become successful invaders in the new areas, thus representing a serious problem for wildlife, agriculture and even human health. Parasites have been proposed to play a major role on bird invasions, facilitating or limiting colonization and spread of their avian hosts in new continents and islands. Several hypotheses could be applied to explain the role of parasites in avian invasions. The *Novel Weapon Hypotheses (NWH)* builds on the idea that invasive bird species gain advantages over native birds by bringing their own parasites to the new environments against which the introduced species but not the natives have evolved defenses. These co-introduced parasites may switch to native hosts and spread in the new communities, hence becoming themselves invasive parasites provoking serious damages to indigenous bird species. But the role of parasites in invasions may extend well beyond such direct effects, and hence some indirect species may also be expected. In this sense, the *Enemy Release Hypothesis (ERH)* poses that non-native bird species could become invaders because they have lost their co-evolved malaria parasites during the process of colonization, and thus they may increase their competitive ability and displace native species in the new areas. Conversely, the *Biotic Resistance Hypothesis* states that native parasites in the indigenous species may reduce the fitness of the potential bird invader and prevent its spread and establishment.

Malaria species are among the most pathogenic species of poultry and wildlife birds, being responsible of economic losses, mass mortality,

population declines and even extinctions of many bird species worldwide after its introduction outside its native range. For all these reasons, the International Union for Conservation of Nature classifies avian *Plasmodium* to be among the 100 of the world's worst invasive alien species. In this review the authors will recapitulate the main scientific contributions showing the role of avian malaria parasites in the global spread of their bird hosts, evaluating the characteristics of both bird host and malaria parasite to become a fruitful invader. They will also highlight the extinctions and endangerment of numerous native species provoked by avian malaria invasions through the world (Hawaii, New Zealand, Galápagos Islands), and new menaces of avian malaria invasions in America.

Chapter 3 – Globally, biological invasion is a threat to economy, biodiversity, and human health. Most of the alien species were mediated by human activity, which is true for aquatic invasion species as well. China has become the world's second largest economic entity and the world's first aquaculture and fisheries trade powers. A total of 544 alien invasive species, including 51 of 100 of the world's worst invasive alien species, have successfully invaded China and have caused great damage to ecological environment, economic development, and public health; ultimately caused by the increase of trade, tourism and logistics. To date, however, few systematic reviews existed to summarize the process, impact and management measures concerning invasive species, especially for aquatic non-native invasive species in China. Here in this chapter, the authors first reviewed the advance of aquatic animal invasion, including the definition of aquatic animal invasion and their unique presence in the world biological invasion. Secondly, they listed 31 main invasive and potential nuisance aquatic alien animal species, 221introduced species including 100 aquaculture animals and 121 ornamental fish, summarized the ecological impact, economic loss and invasion progress, and gave some examples with respect to ecologic destruction. Thirdly, taking apple snail (*Pomacea canaliculata*) and fish as examples, the authors comprehensively analyzed the management strategy, and the current prevention and control measures for invasive alien aquatic animals. Finally, they gave some suggestions about the future management and research topics of aquatic animal invasion.

Chapter 4 – Natural grasslands are one of the ecosystems that have suffered the most intense series of human changes, even though they have not received enough conservation efforts. The proliferation of invasive shrubs and trees over grasslands and savannas around the world has been one of their severest modifications during the last century. The last remnants of South

American Pampas are not the exception, with a set of invasive plants of diverse origins thriving over native biodiversity. Among them, those producing animal-dispersed fruits represent a case of particular interest. St. Lucie's cherry (*Prunus mahaleb* L.) is a small fleshy-fruited tree native to Eurasia that invades natural grasslands in Southern Pampas, where the authors registered twenty animal species contributing to its dispersal.

In this chapter, the authors analyze temporal variations in flowering and availability of ripe fruits at the individual and population level. The species phenology in the area matches with reports from its native range, showing short flowering (19-22 days) and fruiting periods (27-34 days). Synchronicity in flowering and ripening of fruits are consistent with generalist strategies in plant-animal interactions, maximizing cross-pollination probabilities and the attraction of several generalist dispersal agents. The authors postulate that the lack of reproductive phenological overlapping with similar plants may play a key role in its invasion success. Their results suggest that the protection and shading of other trees might permit the fruits to remain in good condition in the canopies for the frugivores during longer periods. In early January, a massive fruit fall occurs and this might change the main dispersal role from birds consuming fruits in the canopies to mammals eating them directly from the floor, being the formers more related to short-distance dispersal and the latter possibly associated to long distance spread. Big trees with high density of fruits beneath the canopy might act as attraction foci to mammals and might have a key role in promoting long-distance dispersal. This suggests that part of the control efforts should be devoted to manage fruit availability in those attraction foci. *P. mahaleb* reproductive biology and its interactions with dispersal agents can explain to a considerable extent its invasive capacity in the study site and offer valuable information for its management. Incorporating these perspectives on mutualisms and invader-ecosystem interactions might improve the ability to predict invasion processes and contribute to better management decisions in other ecosystems invaded by similar fleshy-fruited species.