
INVASION BIOLOGY: AN EMERGING FIELD OF STUDY¹

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ABSTRACT

Biological invasions are increasingly recognized as a key problem for the conservation of biological diversity. However, the scientific recognition that some species, when introduced outside their native range, cause a decline in indigenous species, goes back to at least the writings of Charles Darwin. In the 1950s another British biologist, Charles Elton, wrote the first book attempting to describe the biology in invasive organisms. It was not until the 1980s, however, that the field of invasion biology as a discipline began to emerge. This emergence has resulted from two forces: the development of the scientific basis for invasion biology based on a substantial and accumulating literature, and the urgency of the invasive species issue because increased world trade and travel are increasing the frequency of invasions.

Key words: invasion biology, scientific history, Systematics Symposium.

THE HISTORICAL CONTEXT

Over the last 20 years biological invasions have gained growing attention from ecologists. From the rapid increase in both scientific and popular articles and books written about invasions one might conclude that invasions are a relatively new phenomenon. In fact, as humans first began to move around the earth, they took familiar plants and animals with them for use as food, medicine, or technology (Fritz, 1994). We know that maize was found in eastern North America when European explorers first arrived in the New World, yet this species is known to have originated in Mesoamerica. Its presence so far from its origin and its common use by Native Americans in eastern North America suggest that it was likely traded and carried by indigenous people to the region prior to the arrival of Europeans. And some species are known to “hitchhike” along with human travelers. The Polynesian rat (*Rattus exulans*) was probably brought to islands by the early Polynesians (Merlin & Juvik, 1992), most likely as an accidental introduction.

Charles Darwin provided the necessary context for understanding the biological invasion problem almost 150 years ago. One of the observations that stimulated Darwin to conceive of evolution by nat-

ural selection was that each new continent or island he visited, despite similar environments, had different species. He wrote (Darwin, 1859: 343): “In considering the distribution of organic beings over the face of the globe, the first great fact which strikes us is that neither the similarity nor the dissimilarity of the inhabitants of various regions can be wholly accounted for by climatal and other physical conditions. . . . There is hardly a climate or condition in the Old World which cannot be paralleled in the New . . . [yet] how widely different their organic productions [that is, their species]!” Today we understand fully that the diversity of species on our planet is, in part, the result of continental separation, producing the geography of life that so intrigued Darwin and all biologists since. However, this geography sets up one of the most profound threats to the Earth’s diversity. Because the continents differ more in species than climates, each continent has the potential to provide invaders to other places. Humans are a potent force for assisting that invasion.

In their natural settings, species are found with friends and enemies. Darwin realized that this ecological context provided the ultimate check on unfettered population growth. Thus, there is another important perspective to the invasion problem: we

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often transport species without their coevolutionary context. This may result in poor performance (e.g., if a plant lacks a pollinator), but it may also result in the potential for rapid population growth (e.g., if the species is free from natural enemies or other constraints). Darwin (1859: 370) also recognized that some introduced species may threaten native species. In his chapter on geographical distributions he reported, “. . . many European productions cover the ground in La Plata, and in a lesser degree in Australia, and have to a certain extent beaten the natives. . . .” This may be the first scientific comment on invasions.

Although there were studies of invasions in the years since Darwin, biologists and ecologists did not focus on the magnitude of the growing problem until 1958 when Charles Elton ([1958] 2000) published a book that has come to be regarded as the seminal volume in this field of study. *The Ecology of Invasions by Animals and Plants* is a slim book borne from his observations as an animal ecologist. Three 1957 BBC radio broadcasts he developed on the subject of “Balance and Barrier” apparently stimulated Elton to write a book on invasions, aimed at a lay audience, that laid out what are still the fundamental issues in invasion biology: that each continent has its own unique flora and fauna, that human migration and trade were breaking down the barriers that had led to the uniqueness of the biota, and that this breakdown of the barriers could have severe consequences for the maintenance of diversity. The book is amazing in its prescience and yet was in large part underappreciated until the 1980s, when it became widely recognized that the invasion of non-native species was one of the biggest threats to naturally occurring species and ecosystems.

In 1982 the Scientific Committee on Problems of the Environment (SCOPE), a committee of the International Council of Scientific Unions, met in a general assembly in Ottawa. At that meeting the invasive spread of plants, animals, and micro-organisms introduced by humans outside their native ranges was identified as a problem of global concern, amenable to interdisciplinary synthesis. This determination led to a number of symposia held around the world in the mid 1980s and resulted in two important books (MacDonald et al., 1986; Mooney & Drake, 1986) that both address three important questions: (1) What are the factors that determine whether a species will be an invader or not?; (2) What are the site properties that determine whether an ecological system will be relatively prone to, or resistant to, invasion?; and (3) How should management systems be developed using

the knowledge gained from answering these questions? Each symposium consisted of distinguished biologists, most of whom worked in related areas of study, though not specifically invasions, attempting to answer these questions from their understanding of the biota of their continent. These volumes (e.g., MacDonald et al., 1986; Mooney & Drake, 1986) serve as “state of the knowledge” documentation and are notable for their general lack of specific data on invasions. This was because there were few studies specifically on invasions from which to draw conclusions. Reading the chapters, it appears that more questions were developed than answered in the course of the symposia and book production. These books fueled the newly emerging field of invasion biology, as a generation of graduate students read the chapters and seized the opportunity to attempt to answer the questions derived during the SCOPE process.

In the approximately 15 years since the publication of the SCOPE books the field of invasion biology has not only influenced the content of many biological journals, but it has also developed its own journal (*Biological Invasions*, Kluwer Press), its own set of terminology, and its own set of raging scientific debates. While the SCOPE volumes provided the initial fuel for the scientific field of invasion biology, it was the mounting evidence of severe environmental degradation that focused the attention of so many people on invasions. For instance, invasive species were identified as significant threats to biodiversity at more Nature Conservancy preserves with completed conservation plans than any other type of threat, including development, fire suppression, and altered hydrology. In fact, 94% of those sites responding as of the summer of 2000 listed invasive species as a serious problem (J. Randall, The Nature Conservancy, pers. comm.). In 1998, a study found that invasive species were second only to habitat destruction and fragmentation in threatening endangered species in the United States (Wilcove et al., 1998). This study reviewed listing information for species proposed as endangered or threatened under the Endangered Species Act and found that 49% of the imperiled species were in that condition at least in part because of invasive species.

FUTURE CHALLENGES

With the recognition that invasive species are one of the most serious conservation concerns today, there has also been the recent realization that the problem is getting worse very rapidly. Globalization of trade and advances in technology mean

that species are moving around the earth more frequently and are coming from some places, such as China, that have been closed off from most of the rest of the world during the last several decades. For instance, the Asian long-horned beetle (*Anoplophora glabripennis*), which is native to China and considered to be a pest there, was first detected in the Greenpoint neighborhood of Brooklyn, New York, in 1996. The United States Department of Agriculture subsequently determined that the insect arrived in solid wood packing material on goods imported from China. Not only are new pathways opening, but the journeys that used to take weeks by ship may now take hours by plane, allowing more organisms to survive the trip. Trade agreements and organizations such as the North American Free Trade Agreement (see NAFTA website, 2002), launched in January 1994, and the World Trade Organization (see WTO website, 2002), formed in January of 1995, limit the restrictions that signing countries can place on the entry of trade goods. Many invasive species are introduced either as trade goods themselves, in the case of some plants and animals, or as contaminants of trade goods, such as insects found in shipping dunnage and pallets.

Just as international trade has increased, so has pleasure travel. Tourism has become a major sector of the U.S. economy, with current figures of about \$110 billion a year (up from about \$26 billion in 1986). Over 46.5 million international visitors entered the United States in 1996, with a projected annual growth of 3–4% (Doggett, 1997), although tourism may decline over the next several years as a result of fears regarding safety in traveling. Travelers often inadvertently carry invasive species as hitchhikers on their person or property, but they also may intentionally bring in species. For instance, 16,997 international passengers checked during one week in May 1990 at the Los Angeles International Airport were found to be carrying 1357 lots of fruits and vegetables and 325 lots of animal products, for a total of 2635 kg of contraband material (U.S. Congress, 1993). They may bring species with them for personal use or as gifts for friends and family.

To address the problems caused by invasive species and the many pathways by which they enter, we must work with the deliberate intention of re-

ducing the entry and impact of such species. As scientists, we will need to ensure that our science is not only viewed by our peers, as is traditional, but that agencies managing invasive species are also aware of our findings. As scientists we must learn from the past, examine the present, and plan for the future. As the field of invasion biology moves into its adolescence, it will continue to test theories basic to ecology and to form new hypotheses to address the novel situations that arise following the introduction of new species. These discoveries, if implemented in management and policy practices, may play a substantial role in lessening environmental degradation through invasions.

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