



U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Wildlife Services

U.S. Government Publication

1 Introduction

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Vertebrate species have been introduced to almost all parts of the world for thousands of years. Within the United States and its territories alone, over 1000 vertebrate species have been introduced since the early sailing ships explored the world. This includes at least 86 species of mammals, 127 species of birds, 126 species of reptiles, 53 species of amphibians, and over 673 species of fish (Witmer and Fuller 2011). Many of these species were native to the United States, but were moved to novel regions, often unintentionally or intentionally by humans. While invasive vertebrates have been introduced to all parts of the world, in this book, we focus on introduced terrestrial vertebrates in the United States and its territories, and the intention is to provide an overview of the complexity and challenges associated with managing invasive species within the United States. Often, the management of invasive species and the prevention of new species becoming established is largely a function of the regulatory framework established within a specific country. In this book, although historical management successes and failures are discussed, the focus is on current effective management options and potential future developments to minimize the effects of invasive species and prevent their spread into new areas.

Although plants and animals have been introduced into new areas for centuries, the increased volume of worldwide trade and transportation has accelerated the rate of species introductions over the last 150 years. Animals are introduced for many reasons, both purposeful and accidental. Intentional introductions include both legal and illegal activities such as the production of food and fur, work animals, sport hunting opportunities, companion animals, aesthetics, pets, pet trade propagation, religious purposes, and pest control. Accidental introductions occur because of stowaways in transport vehicles, hitchhikers or stowaways in or on other commodities, escapees, and, in some cases, because of range expansion of a species, often facilitated by human activities and land use. For example, a tropical storm is thought to have brought the cattle egret *Bubulcus ibis* to North America (Florida initially) from the Caribbean islands after they had crossed the Atlantic Ocean from Europe and Africa. However, it may have been agricultural land use that allowed its subsequent rapid range expansion westward across North America. Likewise, habitat fragmentation stemming from anthropogenic land use has facilitated the expansion of coyotes (*Canis latrans*) across the Eastern United States and far south into Central America over the last several decades, reaching areas where the species formerly did not occur.

Many introduced vertebrate species have provided important resources and economic gains for humans and do not cause undue adverse effects, especially with appropriate management. Others have caused serious adverse effects, including

disease and safety hazards, predation and competition with native species, crop consumption and contamination both in the field and during storage, livestock predation, and, in some cases, significant environmental degradation. On many islands, such as Hawaii and Guam, invasive species have caused the extinction of many native species and produced cascading effects across ecosystems. Unfortunately, for many species of introduced vertebrates, it is not yet known if they are causing, or in the future will cause, significant harm to the environment or human resources.

While there are a number of biotic, abiotic, and environmental attributes that contribute to the establishment of an invasive species, there are several underlying themes shared by many successful invaders. For example, species that have high reproductive rates or few effective predators in their introduced range can often quickly establish new populations. Similarly, species with broad dietary or other niche requirements often are better equipped to take advantage of available resources in a new area. Species that are small or secretive generally do well because they can avoid interdiction efforts and go undetected while becoming established. Species that have a wide tolerance to climate have more opportunities to invade and are able to survive in transport. Because many transportation opportunities are in human population centers, species that live in close proximity to people are more frequently transported. Some places are also more vulnerable to invasive species than others. For example, transportation hubs allow for greater opportunities for invasion, and obviously, more species are able to adapt and thrive in areas with less extreme climates. Areas that are geographically isolated, such as islands, tend to have fewer native species that may compete or prey on a recently introduced species. Additionally, habitats that have been altered by people or other invasive species provide opportunities for invasive species to establish.

The President's Executive Order 13112 (1999) set the stage for formally addressing invasive species issues in the United States. This brought attention to the large number of invasive species in the United States, the increased rate of new introductions, and large amounts of economic and environmental damage caused by invasive species. In that document, invasive species are defined as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health." The National Invasive Species Council (NISC) was formed and directed to coordinate across federal agencies in the resolution of invasive species problems. As part of these efforts, NISC put together a National Invasive Species Management Plan which is periodically revised. The plan gives background information on invasive species and the damage they cause, but also makes specific recommendations on how those problems can be removed or lessened. The plan also details five strategic goals: prevention, early detection and rapid response, control and management, restoration, and organizational collaboration.

A wide array of methods is used to manage invasive vertebrates and the damage they cause in the United States. The methods vary somewhat by taxonomic group, and the long-term management of invasive vertebrates is conducted similarly to managing any wildlife damage situation. Methods include traps and snares, netting, shooting, frightening devices, decoys, toxicants, dogs, Judas animals, purposely introduced predators, habitat manipulation, barriers, and sterilants. In some cases, cultural methods may also be used (e.g., sanitation, the type of crop selected and the

timing of planting and harvest, compensation and insurance programs, etc.). Details on most of these methods, how they are used, and their advantages and disadvantages are presented in the various chapters of this book and elsewhere.

Eradication strategies are more complex and are discussed using species from various taxonomic groups in the chapters that follow. Eradication generally involves careful planning, new methods development, appropriate timing, and an adequate allocation of personnel and resources. Having an informed and supportive public is also a critical component to achieving success in the eradication of an invasive species. Additionally, follow-up monitoring is essential to assure that a successful eradication has been achieved and to address and respond to a reinvasion, should that occur. Fortunately, there have been numerous successful eradications of invasive vertebrates in parts of the United States. This includes invasive rats and mice, feral goats, and feral cats.

Managing invasive species is a challenge because they often can be difficult to detect, and damage may go unnoticed for a period of time. Another challenge is the need to develop new methods to manage or detect species. We often turn to traditional tools to manage new species, but our ability to control a new invasive species often requires the development of novel tools. This was certainly the case with the brown tree snakes (*Boiga irregularis*) in Guam. There may be resistance to control efforts before effects are widespread because most people do not see the need. Further, some people do not like management of animals (e.g., feral cats, *Felis catus*) that are commonly kept as pets, regardless of the extent of damages they inflict upon native species or ecosystems. Additionally, funding for interdiction efforts and invasive species management is often limited—yet costs to mount large-scale efforts against well-established species are extremely high.

Most of the management and research for invasive species can be put into two broad categories of activities, prevention/detection and control/eradication. Prior to the establishment of a species, efforts are often focused on prevention and early detection, as well as awareness of potential impacts. During this time, communication among groups is critical to avoid duplication of effort and to maintain a clear channel for the reporting of new introductions or incipient populations. Unfortunately, often no action is taken until the invasive species is well established, after which efforts typically shift towards documenting impacts and the development of control or, potentially, eradication strategies. Public education is critical throughout both stages. However, the same line used to demarcate the establishment of a species could also be referred to as the money line because funding typically available to manage species is often only available after a species is well established and proven to be harmful. Before a species is established, there is limited funding for research and management due to a lack of public interest and knowledge of potential consequences. Why spend money now if we don't have to? However, the irony is that reactive management of invasive species after they have become well established is far more costly, and the probability of success is greatly reduced compared to proactive strategies. Nonetheless, once a species is established and is having ecosystem, economic, and/or human health effects, public interest increases and funding becomes available. Thus, if we can shift our efforts and resources to developing tools for interdiction and preventing new species from becoming established, we can manage invasive species much more effectively.

Given the global ecological and economic impacts of invasive species, as well as the complexities and costs associated with control and eradication efforts, invasive species represent one of the greatest challenges facing agencies and managers today. Through the integration of numerous and specific case studies, this book highlights the impacts and control efforts for many prominent invasive terrestrial vertebrates in the United States. The book is organized into three sections. The first section reviews the context in which management occurs and addresses the current U.S. policy and regulation, biosecurity threats and risk assessment, and the economics of vertebrate invasive species management. The second section provides an overview of environmental, agricultural, societal, and ecological impacts from invasive species. The last section provides case studies related to noteworthy and well-established terrestrial invasive amphibians, reptiles, mammals, and birds. Specifically, these case studies illustrate the impacts associated with these species, the unique challenges associated with management, and potential management options that could be developed. The management of established invasive species and reducing their impacts is extremely challenging, but significant progress has been made for many species as will be detailed in the chapters that follow.

REFERENCE

Witmer, G.W., and P.L. Fuller. 2011. Vertebrate species introductions in the United States and its territories. *Current Zoology* 57: 559–567.