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6 Contribution of the Live Animal Trade to Biological Invasions

6.1 Introduction

Live animals are an important biological commodity, and their trade causes the global movement of millions of individuals annually (Fernandez & Luxmoore, 1997). Although the trade in live animals has a long history, dating back to at least Greek and Roman times, the emphasis was most often on novelty and exotic foods for the noble classes (Lever, 1992; Cassey *et al.*, see Chapter 2). Today, the ability to obtain live animals is no longer restricted to nobility, and species are traded widely for a variety of purposes. Advances in air transport and shipping techniques have facilitated the movement of more species and individuals used for the live animal trade than in the past (Roe *et al.*, 2002; Fuller, 2003). The trade in live animals is largely unregulated (Smith *et al.*, 2009), and the number of non-native introductions through this pathway continues to rise; therefore, future introductions and their associated impacts will continue to be of concern (Kraus, 2003; Goss & Cumming, 2013).

This chapter describes the live animal trade, the specific pathways through which animals are transported, and how each pathway has contributed to species introductions worldwide. The term pathway is considered here as the specific purpose for which a non-native species was transported to an area beyond its native range. I have attempted to further break down the live animal trade pathway into sectors based on the purpose for trade, but the boundaries that separate each sector can be fuzzy, and cannot be considered mutually exclusive. Many species are traded for more than one purpose, and can also be introduced through multiple pathways. I primarily focus on the pathways for tetrapods; a summary of the pathways of invertebrate and fish invasions is covered by Fuller (see Chapter 5). I have provided several examples from the United States, in large part because these events are well-documented, and also because it reflects my experience. However, I do include additional information with examples drawn from around the world.

Introduction is defined here as the occurrence of a species outside of its native range, regardless of whether the species is of foreign or domestic origin (i.e., individuals of a species within a country that are transplanted outside their native range). I include here discussion of introductions of species that have become established (breeding population) as well as those that did not do so. While introduction of one individual is typically not enough to establish a viable population, it is still important to document that species' presence outside of captivity because it records a trend of escaping or being intentionally released.

6.2 Captive Animals

This section describes the reasons for which animals are traded specifically to be kept in captivity for non-scientific purposes. The patterns by which animals are kept in captivity differ by geography and culture. For example, from animal ownership surveys conducted in Indonesia, Costa Rica, and the United States, the percentage of households that owned birds were 35.7% (Jepson & Ladle, 2005), 23.3% (Drews, 2001), and 3.9% (American Veterinary Medical Association, 2007), respectively. As far as scale, it is important to consider that 3.9% of households in the United States translates to about 11 million birds in captivity, whereas 35.7% of households in Indonesia refers to about 2 million birds in captivity. Some animals described in this section can be loosely categorized as “pets”, but I also include here animals that are kept in captivity for a variety of purposes. Introductions for most vertebrates in trade occur through the pathways described here; therefore, this section is particularly thorough.

6.2.1 Pets

The definition of pet can vary widely: from companion animals to animals kept as part of a more impersonal menagerie or collection. The types of pets can range from domesticated animals, such as dogs and cats, to those that are collected directly from the wild. Dogs and cats are excluded from this chapter, as their trade and introduction history is a topic too expansive to be suitably covered here.

Birds have the longest history as captive animals. Records of birds in captivity, such as mynahs and parrots, date back to at least 1000 BC in Asia (Law, 1923). There are various motivators for keeping birds: for their aesthetic value, their song, their ability to mimic speech, their ability to bond to their owners, and for the social status they can bring (Beissinger, 2001; Shepherd *et al.*, 2004). The importance of each of these motivators differs among cultures. For example, in Taiwan, passerines are valued for their song (Su *et al.*, 2014), whereas in the United States parrots are more popular for their ability to interact with their owners (Anderson, 2003).

The captive bird trade was active in Europe by the 1800s, and the United States followed suit by the mid-1800s. By the late 1800s, Oldys (1907) estimated that approximately 700 species and 800,000 individuals were imported into Europe, and more than 200 species and 300,000 individuals were imported into the United States. The global trade in wild birds peaked in the mid-1970s, and it was estimated that about 7.5 million birds were traded annually. In the 1990s, this number declined to about 3 million birds annually. More recently, these figures have dropped further, owing to the enforcement of international regulations related to bird conservation and human health, such as the United States Wild Bird Conservation Act of 1992, and the European Union’s ban on wild bird imports in 2007 (FAO, 2011). While the decline in

these numbers seems encouraging, birds are still removed from the wild at unsustainable numbers, and trade in some regions is, in fact, increasing.

For most countries in Latin America, Africa, and Asia, the keeping of birds is centered around native species, rather than the importation of non-native species. For example, it is estimated that before 2008, most of Mexico's parrots caught in the wild were sold at markets within Mexico's borders (Cantú *et al.*, 2007). However, after Mexico banned the trade in native parrots, the country quickly surpassed all others in the importing of CITES-listed species, mostly Monk Parakeets (*Myiopsitta monachus*) (CITES trade database, <http://trade.cites.org/>).

In the last 30 years, there has been a surge of interest in amphibians and reptiles as pets, both in the United States and abroad (Hoover, 1998; Auliya, 2003; Tapley *et al.*, 2011). The United States and the European Union are the primary consumers of reptiles and amphibians as pets. In the United States, the quantity of individuals imported from some of these groups has more than doubled since the early 1970s. For example, approximately 320,000 lizards and snakes were imported per year in the early 1970s, and over a million individuals were imported per year in the early 2000s (Romagosa, 2015). Many individuals imported in recent years belong to just a few species that are popular pet animals, such as green iguanas (*Iguana iguana*), Chinese water dragons (*Physignathus cocincinus*), and ball pythons (*Python regius*).

Interest in a more diverse selection of amphibian and reptile species for pets has been accompanied by an increase in the number of species imported from these groups. This phenomenon is particularly apparent in the diversity of lizard species; the number of lizard species imported in 1970–71 (176 species) versus 2009–10 (287 species) increased by 63% (Romagosa, 2015). The trade in these groups for pets is also increasing in Asia, where the most commonly kept reptiles are turtles (Zhang & Yin, 2014). Many consumers view reptiles and amphibians as an easy-care pet, as these pets often do not require as much attention as birds and mammals. Unfortunately, many consumers either receive erroneous or no information regarding their care and find themselves unprepared for the adult size and longevity of some species, leading to the introduction of unwanted animals to the wild.

The trade in live mammals as pets has never exhibited the species diversity and scale seen in other taxonomic groups. Non-human primates are popular as pets around the world, and have been so for thousands of years (Mack & Mittermeier, 1984; Hughes, 2003). In wealthy regions, such as the United States, European Union, and Japan, the interest in small mammals as pets is increasing. Gerbils, hamsters, guinea pigs and rabbits have long been common, but unique animals such as sugar gliders, degus, and prairie dogs are increasing (Grier, 2006; Lennox, 2007; Jekl *et al.*, 2011; Moutou & Pastoret, 2010). Trade in captive-bred desert hamsters (*Phodopus* spp.) in the United States has increased at an alarming rate, with approximately a million individuals imported between 2004–2013, and with no record of their importation before 1998 (Romagosa, 2015). Given the penchant for small mammals to escape their enclosures (Long, 2003), the sudden appearance in trade of such a quantity of animals is of concern.

When it comes to releases of individuals into the wild, the pet trade is cited as the primary pathway for vertebrate introductions (Kraus, 2003). Some of these introductions are accidental, and some are intentional. Any owner of these animals can attest that some of these groups are particularly prone to escaping (Owre, 1973; Pyšek *et al.*, 2010). Unfortunately, these animals can also be intentionally released by irresponsible or naïve owners. At a somewhat larger scale, there can be releases by breeders or dealers. For example, James (1997) reported that in addition to accidental escapes, dealers of exotic pet birds often release large numbers of recently imported birds to avoid quarantine restrictions, and aviculturists purposely release other unwanted birds. Unauthorized release of pets and surplus commercial stocks are not limited to birds; the release of non-native fish, mammals, amphibians, and reptiles also occurs with increasing regularity around the world (Kraus, 2009; Krysko *et al.*, 2011; Witmer & Hall, 2011; Fuller, see Chapter 5). As an additional source of introductions, in Brazil it was noted that the authorities will often release birds and reptiles after they have seized illegal animals (Destro *et al.*, 2012). Issues of genetic introgression, where non-native species interbreed with native species, abound with animals released through the pet trade.

To further complicate introductions, some species are released intentionally to create a wild breeding stock, to then funnel back into the pet trade (Kraus *et al.*, 2012). Other non-native populations, perhaps not intentionally released for re-sale, are also harvested for the pet trade (Krysko *et al.*, 2004). Once an established population is well known among the public, people may also release their unwanted animals into that population. For example, people have been caught illegally releasing their unwanted pet iguanas in a well-established population on Key Biscayne, Florida (Krysko *et al.*, 2010). Finally, additional populations can also be seeded across a region, creating challenging management scenarios, as seen in Florida and Hawaii with chameleons (Kraus *et al.*, 2012; Rochford *et al.*, 2013).

6.2.2 Competition

Birds are also kept for singing competitions in parts of Europe, Latin America, and Asia (Nash, 1993; Anderson, 2005; Hanks, 2005; Birkhead & Van Balen, 2008; Gama & Sassi, 2008; Alves *et al.*, 2010; Su *et al.*, 2014). While song has always been a large component of the appeal of keeping birds, the species selected for this purpose can differ from those species simply favored for song. In each region, specific bird species are prized for their singing abilities for competition: Europe, Chaffinch (*Fringilla coelebs*; Birkhead and van Balen, 2008); South America, seedeaters (*Oryzoborus angolensis* and *Oryzoborus crassirostris*; Hanks, 2005); Asia, the Zebra Dove (*Geopelia striata*), Canary (*Serinus canaria*), Black-throated Laughingthrush (*Garrulax chinensis*), Chinese Hwamei (*Garrulax canorus*), Orange-headed Thrush (*Zoothera citrina*), White-rumped Shama (*Copsychus malabaricus*), and Oriental Magpie-robin (*Copsychus saularis*) and various white-eye species (*Zosterops* spp.) (Shepherd *et al.*, 2004; Jepson & Ladle,

2009; Shepherd, 2011; Jepson *et al.*, 2011). An additional bird-keeping subculture includes birds kept for fighting competitions. For example, the Saffron Finch (*Sicalis flaveola*) is used for these types of competitions in Brazil (Gama & Sassi, 2008).

Many of the species described above have established wild populations. Exemplary singers can fetch high prices, and the release of inferior individuals has been documented (Nash, 1993; Li *et al.*, 2010). Additionally, there is evidence that interbreeding between subspecies and/or races of birds has occurred at a regional scale. Examples of this admixture include the Oriental Magpie-robins in Singapore (Sheldon *et al.*, 2009) and the Chinese and Taiwan Hwamei (*Garrulax canorus* and *G. taewanus*) (Li *et al.*, 2010). As people emigrate from their respective countries, so do their pastimes. The Guyanese pastime of bird racing has been documented in New York (Sell, 2009), and finches used for fighting contests by Brazilian immigrants were seized by officials in Connecticut and Massachusetts in 2009–2010 (Peters, 2010). At this point in time, the species associated with these pastimes have not been documented in the wild at these locations.

6.2.3 Religious Purposes

The release of animals for religious purposes, known as merit release, is prevalent in many parts of Asia, but has also been documented in North America and Australia (Liu *et al.*, 2012). The modern-day ritual of merit release has changed considerably from traditional practices, and quantity of animals necessary to supply the demand is enormous (Shiu & Stokes, 2008; Agoramoorthy & Hsu, 2005). Birds tend to be the most common taxonomic group used for this practice (Severinghaus & Chi, 1999), but individuals from all taxonomic groups, from invertebrates to mammals, are captured from the wild solely for this purpose (Liu *et al.*, 2012). An estimated annual sale of 680,000–1,050,000 birds for release in Hong Kong alone exemplifies the potential scale of the practice across the region (Chan, 2006). The birds selected for this trade tend to be small, inexpensive, and typically lack the attractive plumage and song that are in demand for pets or singing contests (Severinghaus & Chi, 1999; Edmunds, 2011). In much of Asia, birds sold for this purpose are typically wild-caught native species, though as wild populations decline, more non-native birds are being imported (Nash, 1993). Many of these imported birds have been documented with avian flu (H5N1), and therefore represent a risk of disease transmission to other birds as well as humans (Chan, 2006). Turtles and amphibians are also common merit release animals, but these individuals tend to be captive-bred or farmed non-native species, such as the slider turtle (*Trachemys scripta*) and bullfrog (*Lithobates catesbeianus*) (Severinghaus & Chi, 1999; Liu *et al.*, 2013).

Several species of birds have established populations through merit releases in Hong Kong, Singapore, and Taiwan (Gilbert *et al.*, 2012). As in the case for birds kept for song, interbreeding has resulted in genetic introgression among native and non-native

bulbuls in Taiwan (Gilbert *et al.*, 2012). Merit releases of bullfrogs and sliders, both among the 100 worst invaders in the world (Lowe *et al.*, 2000), add to the numerous pathways by which these species have established wild populations (Liu *et al.*, 2012).

6.2.4 Private Zoos/Tourist Attractions

All across the world, there have been zoos or menageries, travelling circuses, and tourist attractions that have displayed animals. These types of collections have been in existence since Ancient Egyptian times, and persisted through Ancient Greece and Rome until today (Hoage *et al.*, 1996). Animals from all taxonomic groups were found in these collections, and became the source of various established populations (Hughes, 2003). This sector is not as important a source for vertebrate introductions, but introductions have occurred. Hulme *et al.* (2008) reports the escape of 48 bird and 20 mammal species from zoos in Europe, and Kraus (2009) reports the release of 17 reptile species from zoos worldwide. Some of these introductions are notable, such as the escape and establishment of Sacred Ibis (*Threskiornis aethiopicus*) populations throughout Europe (Clergeau & Yesou, 2006). Releases from private menageries have also occurred; among the oddest is the establishment of the hippopotamus in Colombia (*Hippopotamus amphibious*) (Valderrama-Vásquez, 2012).

In the United States, after the Federal Highway Act of 1921 encouraged the building of national highways (Drumm, 2009), roadside animal attractions began to appear across the landscape (Mays, 2009). Animals were released to populate some of these attractions, and then many of the attractions closed after they were circumvented by the routes taken by larger interstates, and the style of American travel and tourism began to change (Drumm, 2009; Mays, 2009). In some cases, their closure led to the additional release of animals once housed there. Most primate introductions in the state of Florida are reported to be due to previous tourist attractions (Layne, 1997).

6.3 Exploitative Trade

This section describes the trade in vertebrates specifically for their exploitation. These pathways are ones where the end destination of the animals traded is for direct consumption, such as for food or traditional medicine, or for scientific research.

6.3.1 Food - Wild Sources

Consumption of animals sourced from the wild has long existed, traditionally as a protein source for subsistence hunters (Wilkie & Carpenter, 1999). Often these animals will also fulfill a medicinal as well as a nutritional role (Secretariat of the Convention

on Biological Diversity, 2011). The increase in demand for wild meat in urban and international markets drives the movement of these animals from the wild into different regions (Lindsey *et al.*, 2013). Depending on cultural preferences, wild meat is supplied in markets either alive or in parts (MacDonald *et al.*, 2011). In some regions, live animals can be sold for twice the amount commanded for carcasses (Mendelson *et al.*, 2003; Hennessey & Rogers, 2008).

Amphibians and reptiles are important components of this trade. Millions of amphibians are harvested from the wild to fulfill the global demand for frog legs (Warkentin *et al.*, 2009). Commercial frog farming is performing an increasing role in meeting this demand (see Commercial Wildlife Farming), but there is still a large trade in wild-caught specimens (Altherr *et al.*, 2011). Currently, the United States and European Union are the leading importers; Indonesia and China are the primary exporters, although there is also a large domestic market within these countries (Warkentin *et al.*, 2009).

Almost all species of turtles have been used for food (Klemens & Thorbjarnarson, 1995), and the oldest records of the movement of animals for food may be for this group. By the 1600s, live giant tortoises served as a fresh food source for sailors traveling in the Indian and Pacific Oceans. The tortoises transported well, and were able to survive long periods without food or water (Bowman, 1966). These same species were also introduced to several islands (Kraus, 2009).

Currently, countries in Asia are the leading consumers of turtles in the food trade. As the trade in wild-caught turtles for this purpose began to deplete domestic supply, importation of turtles from other regions increased (Ades *et al.*, 2000; Lee *et al.*, 2004). Most turtles in the international trade are intended for Asian food markets. This demand has also encouraged the large-scale farming of turtles in several countries (see section on Commercial Wildlife Farming). A staggering 13 million turtles, both wild-caught and farmed, were exported annually (2002–2006) from the United States, primarily to Asian countries (Romagosa, 2015). The consumption of snakes in China has increased over time, and the corresponding increase in imports suggests that, like turtles, the domestic harvest may be exhausted (Zhou & Jiang, 2004).

After pets, more bird species are used for food than any other purpose (Butchart, 2008). These species are primarily from the Orders Galliformes, Anseriformes and Columbiformes, but there is also a market for small birds. Passerines are considered to be delicacies in some Mediterranean countries (Italy, Cyprus, and Lebanon), and are traded—mostly illegally—for this purpose (BIO Intelligence Service, 2011). Additional groups consumed are Psittacids in South America (Duplaix, 2001), owls in India (Ahmed, 2010), and herons and egrets in China (Lee *et al.*, 2004).

Among mammals, ungulates and rodents make up the largest proportion of biomass collected for food, but primates and carnivores are also common (Fa *et al.*, 2002). Additional groups that dominate the food markets in China include two mustelid species (*Melogale moschata*, *Arctonyx collaris*) and the masked palm civet (*Paguma larvata*) (Lee *et al.*, 2004).

The opportunity for cross-species and zoonotic disease transmission through the consumption of wild animals is high (Karesh *et al.*, 2005; Subramanian, 2012). The SARS and avian flu outbreaks were tied to contact with wild animals in China's live food markets (Karesh *et al.*, 2005; Karesh *et al.*, 2007). The consumption of wild animals slowed after each outbreak, but the tradition has once again gained in popularity, which should lead to resumption in trade (Xu *et al.*, 2007).

6.3.2 Traditional Medicine

Throughout human history, people have used wildlife resources to treat various ailments and improve their overall health (Alves & Rosa, 2013). Live animals are collected from the wild and sold for this purpose throughout the world, as their use in traditional medicine is still prevalent. As mentioned in the previous section, the animals used for food also often serve a medicinal use; therefore trade trends in some of these species are similar. Mammals (primates and carnivores) and reptiles (snakes, lizards and turtles) are most prevalent in this trade, and the largest consumer of these animals and their products is China. The trade is susceptible to shifts due to novel medicinal claims, such as the increased trade in Tokay geckos (*Gekko gecko*) into Malaysia after an unfounded claim was made that the species can serve as a cure for HIV/AIDS (Cailabet, 2013). Tokay geckos already have an important role in the medicinal and pet trades throughout the world. Although Tokay geckos have several established populations outside of their native range, they are protected or harvest-restricted throughout parts of their native range in Asia.

No introductions of vertebrate species have been documented for the medicinal trade, but some do exist for invertebrates. The giant African snail (*Achatina fulica*) was introduced to Hawaii for unspecified medicinal purposes, as well as to Reunion Island (Cowie & Robinson, 2003).

6.3.3 Commercial Wildlife Farming

With increasing human populations, and changing dynamics of demand, the need for a stable supply of live wildlife for various purposes has encouraged the farming of non-livestock animals. The commercial farming and/or ranching of animals now exists mainly to source the food, skin/fur, and pet trades. These operations can produce billions of animals a year, but the legitimacy of some of these operations, and their reliance on wild-caught individuals, has been questioned (Shi *et al.*, 2007; Brooks *et al.*, 2010; Lyons & Natusch, 2011). Wildlife farms have been documented for a variety of animals, including but not limited to: frogs, turtles, crocodilians, iguanas, pythons, rodents, ungulates, and porcupines (Wildlife Conservation Society, 2008).

As an early example, the importance of the frog harvesting industry in the state of California in the late 1800s, and subsequent declines of the native frog (*Rana draytonii*), led to the creation of frog farms and the introduction of the bullfrog to the state (Jennings & Hayes, 1985). With the realization that the demand for frog meat outweighed the supply in wild populations, commercial frog farms popped up all over the world, particularly in Asia and South America. Increased demand for turtles for food and medicinal uses has also led to large-scale farming efforts in various countries such as the United States and parts of Asia. A recent publication estimated that there are over 1000 turtle farms in China with a combined value of more than one billion US dollars (Shi *et al.*, 2007).

Wildlife farming at a large scale almost inevitably results in animals eventually escaping (Mockrin *et al.*, 2005). Populations of ungulates, frogs, and turtles have established in many parts of the world as a result of commercial wildlife farming. Nutria (*Myocastor coypu*), muskrats (*Ondatra zibethicus*), and American mink (*Neovison vison*), escapees from fur farms around the world, are among the best examples of detrimental introductions through this medium (Long, 2003). Evidence also exists for the genetic introgression of turtles from some of these farms in native populations (Shi *et al.*, 2005; Fong & Chen, 2010). The potential for disease transmission within the farms and to native species is also of concern; the farming of bullfrogs has contributed to the spread of chytrid fungus (Mazzoni *et al.*, 2003).

6.3.4 Bait

In the United States, use of salamanders as live bait for freshwater fishing is common. Salamanders from several genera (*Ambystoma*, *Desmognathus*, *Gyrinophilus*, and *Pseudotriton*) are collected from the wild either directly by fisherman, or collected by the thousands and then sold in bait shops (Picco & Collins, 2008; Bonett *et al.*, 2007). These salamanders are transported and then often released into regions different from where they were collected (Fuller, 2003). The successful establishment of tiger salamander (*Ambystoma tigrinum*) and seal salamander (*Desmognathus monticola*) populations are attributed to this pathway (Mabry & Verrell, 2003; Bonett *et al.*, 2007). A few releases of other amphibians through the bait trade have been documented (*Hyla wrightorum*, *Lithobates blairi*), but these species are not known to have established wild populations (Kraus, 2009). It seems likely that many other amphibian species have been moved through this pathway, not just in the United States, but documentation is difficult to locate. The bait trade has been implicated in the spread of ranavirus and chytrid fungus (Picco & Collins, 2008), and is also an important pathway for earthworms, fish and crayfish (Keller *et al.*, 2007; Fuller, see Chapter 5).

6.3.5 Scientific Research/Education

The use of animals for dissection and research dates back to Aristotle's times (384–322 BC) (Nutton, 1995). Since that time, the transport of live animals for this purpose has expanded in both scope and scale. The primary tetrapod groups used for and introduced through scientific research and education purposes are amphibians and mammals.

Amphibians were commonly used for scientific research in the 1880s, and a trade developed in several species specifically for laboratory research and as educational dissection tools (Holmes, 1993). In the late 1930s, a diagnostic pregnancy testing tool was developed using African clawed-frogs (*Xenopus laevis*), which led to a boom in their trade. Even after the development of more modern methods for pregnancy testing, the trade in clawed-frogs and related species still continues, as they are widely used in scientific research as well as the pet trade. *X. laevis* is among the most widely distributed captive amphibian species in the world, and many populations have become established in the wild due to intentional and unintentional introductions by research laboratories and pet owners/suppliers (Measey *et al.*, 2012).

Rodents and lagomorphs are the most common mammalian groups used for scientific research and education purposes. Because many of these species are so ubiquitous, having been introduced all over the world, it is difficult to pinpoint the specific pathway for all wild populations. Non-human primates are another commonly transported group for scientific research purposes. The primate trade for the biomedical and pharmaceutical research markets peaked in the late 1960s and early 1970s (Nijman *et al.*, 2011); several hundred thousand primates were traded for this purpose. The United States was then by far the largest importer of all primates (LeCornu & Rowan, 1978), and remains so today.

Some established populations of introduced primates originate from scientific research animals. For example, some colonies of Rhesus monkeys (United States-Florida, Caribbean, and South America), and chimpanzees (United States-Georgia) were introduced with the specific purpose of establishing breeding colonies from which individuals could be collected for scientific research (Layne, 1997; Long, 2003). Interestingly, populations of *Chlorocebus* monkeys that were established in Barbados and Nevis/St. Kitts in the 1700s are now the primary source for these species in the scientific research trade (Kavanagh, 1984).

6.4 Trade for Direct Intentional Introduction

This section describes the reasons why live vertebrates were traded to intentionally introduce them to the wild. This process has occurred for thousands of years, but

experienced an increase during and after the colonial period. In the 1800s, various Acclimatization Societies were formed across several continents, whose main interest was to introduce non-native plants and animals. These groups did so for various purposes: to improve the aesthetic quality of the environment, to provide animals for sport, and to help control pests. They did so for at least a hundred years until they lost favor among the public and the scientific community (Lever, 1992). Their lofty goals were not abandoned, however. Many individuals and government agencies took matters into their own hands and continued the work started by these societies, albeit in a more rational manner (Lewin, 1971). This section has the most overlap with the previous sections, but a few subtleties deem it worthy of its own discussion. There are many published descriptions about these introductions, as well as a brief treatise of Acclimatization Societies and bird introductions in a previous chapter (Cassey *et al.*, see Chapter 2), therefore I will only discuss them briefly.

6.4.1 Aesthetics

Many birds and, to a lesser extent, mammals, have been introduced to improve the aesthetics of the landscape by Acclimatization Societies as well as other individuals seeking the same goal (Long, 1981; 2003). One of the many bird species introduced was the Mute Swan (*Cygnus olor*) (Phillips, 1928), which is now considered to be a pest in the northeastern United States (Tatu *et al.*, 2007). The majority of the birds released for their aesthetic value around the world include species from the families Psittacidae, Fringillidae, Estrildidae, Anseridae, Anatidae and Phasiandae (Long, 1981). The release of animals for aesthetic reasons still occurs today, and species continue to establish self-sustained breeding populations.

6.4.2 Sport

Game birds and mammals are the primary groups that have been transported and introduced for this purpose. While some species were introduced with the intention of keeping them contained within the boundaries of a preserve, others were fully liberated with the intention of creating wild, free-living populations as a method of game enhancement.

Game birds have been introduced worldwide (Long, 1981), but the documentation of the importation and introduction of game birds is reasonably well documented for the United States. The introduction of game birds in the United States began at least by the mid-1700s (Phillips, 1928; Bump, 1963). Importation of game birds and introductions continued thereafter, some by private individuals and others by various levels of government. More than 1.6 million game birds were imported into the United

States between 1901–1942, most of which were intended for release to the wild (Banks, 1976). The game bird releases by the United States government were formalized as the Foreign Game Importation Program of the United States Fish and Wildlife Service, created in the mid-1940s, and discontinued in 1970. Toward the end of this period (1966–1968) this program released 94,486 game birds (Bohl & Bump, 1970).

The introduction of small and large game mammals has also occurred worldwide, most notably in New Zealand and the United States. Many of these animals have been introduced to game ranches, where the maintenance of wild animals occurs in defined areas delineated by fences. This pathway is the most important in relation to successful mammal introductions (Kraus, 2003). Presnall (1958) reports at least 10 species of ungulates that were introduced to the wild in the United States, and at least 5 of these species still have established populations (Long, 2003). The most successful ungulates introduced worldwide for sport include the wild pig (*Sus scrofa*), axis deer (*Axis axis*), fallow deer (*Dama dama*), red deer (*Cervus elaphus*) and Sika deer (*Cervus nippon*) (Long, 2003). Animals are still transported to stock game ranches, and additional species and populations will undoubtedly establish in the future.

6.4.3 Biological Control

In the late 1800s, several vertebrate species were introduced to serve as biological control agents. These introductions were later identified as ill-conceived because of the impacts the control agents would have on non-target species (Hoddle, 2004). Terrestrial vertebrates that were introduced for biological control of other vertebrates or arthropod pests include: several mustelids, such as the mongoose (*Herpestes javanicus*) and stoats (*Mustela erminea*); the cane toad (*Rhinella marina*); and several species of mynas (*Acridotheres* spp.) (Hoddle, 2004). The trade and introduction of vertebrates specifically for biological control rarely happens today.

6.5 Conclusions

Global trade has increased substantially since the 1950s (Nordstrom & Vaughn, 1999) and, with it, the risk of additional introductions has increased (Levine & D'Antonio, 2003). This phenomenon has created an increase in all biological commodities, including the live animal trade. Characterizing the contribution of trade to biological invasions begins with identifying the various pathways by which animals are transported to new locations. Efforts to understand how species are entrained into the various pathways will lead to better understanding of biological invasions as a whole (Su *et al.*, 2014).

In a nutshell

- The live animal trade is an important commodity market that drives the annual transport of millions of animals worldwide.
- This trade in live animals is the primary pathway for species introductions.
- To help best describe the contribution of the live animal trade to biological invasions in this chapter, it is separated into several pathway sectors, focusing on tetrapods.
- Live animals are traded to be kept in captivity as pets, for competitions, for religious purposes, and for zoos and tourist attractions.
- Pets and merit releases are the most important pathways for the introduction of most vertebrate groups.
- Live animals are also traded specifically for exploitation for food, fur and skins, traditional medicine, bait, and scientific research purposes.
- The demand for animals for exploitation exceeds supply, and commercial wildlife farming has been implemented to meet this demand.
- Animals are also transported to new regions for intentional introductions for aesthetic and sport (game) enhancement, and for biocontrol.
- The introduction of game animals is the most important pathway for mammal introductions through trade.
- Introductions through the live animal trade can be expected to continue with the expansion of global trade in all commodities.

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