Wildlife as Weeds

Jeff Lovich
U.S. Geological Survey
Department of Biology, University of California, Riverside, CA 92521-0427

In 1958, Charles Elton stated *"we are living in a period of the world's history when the mingling of thousands of kinds of organisms from different parts of the world is setting up terrific dislocations in nature..."* Modem ecologists are now well aware of the problems caused by the invasion of exotic species into natural areas and the attendant effects on global patterns of biodiversity (Clout 1995; Randall 1996). Once established, some exotic species have the ability to displace or replace native plant and animal species, disrupt nutrient and fire cycles, and cause changes in the pattern of plant succession (Vitousek 1990; Randall 1996). The magnitude of changes wrought by invasive plant species fostered the development of several organizations, including the Exotic Pest Plant Council (Florida), the California Exotic Pest Plant Council, the Pacific Northwest Exotic Pest Plant Council, and the Tennessee Exotic Pest Plant Council, all dedicated to highlighting the challenges that invasive plant species pose to natural ecosystems and championing the causes of prevention, control and eradication. While this is a worthwhile endeavor, it is important to remember that invasiveness knows no taxonomic limits. Many animals have invasive tendencies and their impacts are often as great as or greater than those of invasive plants.

Humans have transported plants and animals for millennia. The Polynesians brought pigs, dogs, rats and other animals when they arrived in Hawaii (Steadman 1995). The Spaniards brought horses, donkeys, cattle and sheep to the New World. While these are familiar examples, there are many others that are relatively unknown to most people. The purpose of this essay is to highlight a small portion of the portfolio of "weedy animals" and examine their impacts on native ecosystems, with emphasis on the United States. For the purpose of discussion, an exotic or "weedy" animal is defined as a species that is established in an area (where it was historically absent) because of human activities.

How big is the problem and where do weedy animals come from?

The most comprehensive analysis of the impact of exotic species in the United States was published by the U.S. Congress, Office of Technology Assessment (U.S. Congress 1993). According to that report, over 2,300 species of exotic animals are established in the United States, including 142 species of terrestrial vertebrates, over 2,000 insects and spiders, 70 fish, and 91 freshwater mollusks. From 1940-1990, the number of introductions of terrestrial vertebrates, fish and mollusks (combined) has averaged 7.7 species per decade. On a worldwide basis, humans have been responsible for at least 788 introductions of 118 mammal species and 771 introductions of 212 bird species outside of their historically natural ranges (Ebenhard 1988). Most bird and mammal introductions have occurred in the Nearctic, Palearctic and Australasian Realms (Table 1).

It is important to emphasize that introductions can lead to serious ecological consequences even when species are moved within their native country or continent. In the United States, bullfrogs, arctic and red foxes and various fishes have been established far from their historically natural ranges as discussed below.

Table 1.

The geography of higher vertebrate introductions. Species totals differ from text because islands are not included and because of multiple introductions of the same species in different parts of a continent. From Ebenhard (1988).

Realm	Mammals	Birds
Palearctic	37	19
Ethiopian	10	13
Oriental	2	3
Australasian	27	24
Nearctic	32	47
Neotropical	14	9

What determines the success of invasive species?

A variety of factors enhance the success of invading species, including high population growth rate, high fecundity, excellent dispersal ability, phenotypic plasticity, short generation time and preadaptation (Westman 1990). In addition, those animals that prosper in human dominated landscapes are naturally predisposed to invasion in and around cities. These animals can become "subsidized" competitors with native wildlife because of their ability to exploit food, water and shelter provided by, or associated with, human activities (Soulé 1988). By taking advantage of these subsidies, even native species, like ravens (*Corvus corax*) can expand their range and become pests in areas where they did not occur in high densities during historical times (Boarman 1993).

In California wetlands, the most serious threats to native species are posed by omnivorous, predatory, exotic animals like sunfish (*Centrarchidae*), crayfish (*Procambarus* and *Orconectes*) and bullfrogs (*Rana catesbeiana*). Disturbed sites, particularly those at low elevations along the coast, are threatened by the greatest number of invasive exotic animal species (Dudley and Collins 1995).

Weedy wildlife: selected case studies

Fish

Fish have been translocated around the world to enhance fisheries, for aquaculture and for various other purposes. Over 11,000 intentional introductions of 404 exotic fish species or hybrids have been reported in the United States since 1800 (Boydstun and Williams 1995). In addition, as many as 27 exotic species have been introduced accidentally through the trade in aquarium fishes. Ballast water discharge is another significant pathway for dispersal and introduction and is probably responsible for the introduction of the ruffe (*Gymnocephalus cemuus*) in the United States (Bjergo et al. 1995). There is concern that ruffe populations are increasing at the expense of native fish (Edsall et al. 1995).

Mosquito fish (*Gambusia affinis* and *G. holbrooki*), small species native to the southeastern United States, have been introduced around the world for mosquito control. While the intentions to introduce mosquito fish were noble, the species have been nicknamed "fish destroyer" due to their predatory displacement of native species. Competition for resources has also been implicated as a reason for their predominance and they have reduced or eliminated several small endemic fish in the western United States (Lydeard and Belk 1993).

The introduction of game fish such as trout (*Salvelinus* spp., *Onchoryncus* spp.) and bass (*Micropterits* spp.) outside their normal range has contributed to the decline of native aquatic organisms (Loope et al. 1988), including indigenous trout (Behnke 1992). Populations of native frogs in the western United States were eliminated when non-native trout from eastern and western North America and Eurasia were introduced into previously fish-free habitats (Bradford et al. 1993). Causes of the decline appear to be attributable to fish predation and habitat fragmentation due to the presence of predatory fish in portions of drainage networks (Drost and Fellers 1996). In contrast, native fish populations in California streams have a remarkable ability to

resist invasion by exotic fishes when streams are relatively undisturbed by human activity (Baltz and Moyle 1993). Unfortunately, many streams are disturbed and a significant number of California fish are at risk because of the introduction of exotic fish (Moyle et al. 1995).

The impact of exotic fish on native fish has been profound. Exotic fish species caused 68% of the fish extinctions in the past 100 years and contributed to the decline of 70% of the fish listed under the U.S. Endangered Species Act (Li 1995).

Amphibians and reptiles

As a group, amphibians and reptiles have been very successful as invaders. Prior to 1978, 75 exotic species were introduced into the United States in numbers sufficient to allow establishment (Smith and Kohler 1978), including some 50 species in Florida alone (Wilson and Porras 1983). The rate of introduction of exotic amphibians and reptiles into South Florida was fairly constant from 1940-1958. However, from 1958-1983 the rate of invasion increased three-fold (Wilson and Porras 1983). Exotic species of amphibians and reptiles dominate some faunas, as in Hawaii (Table 2).

Some species, such as the cane toad (*Bufo marinus)* were introduced intentionally as agents of biocontrol. Originally native to Central America, the toad has been introduced to tropical and subtropical areas worldwide. For example, cane toads were introduced into Hawaii from Puerto Rico in 1932 to control sugar cane beetles and other insect pests (McKeown 1978). Similar introductions occurred in Florida, U.S. Virgin Islands, the Territories of Guam, American Samoa, and Australia (McCoid 1995). Unfortunately, the cane toad is well-protected at all life stages by skin glands that secrete a highly toxic fluid and many native predatory animals are killed when they attempt to eat the toad (McCoid 1995).

Table 2.

Introduced amphibians and reptiles in various states. Data from Stebbins (1966), McKeown (1978), Wilson and Porras (1983), Dixon (1987), and Conant and Collins (1991).

State	Introduced	Native	% Introducted
South Florida	25	80	23%
Hawaii	18	4	82%
California	9	80	10%
Texas	6[1]	204[2]	3%

[1]south Texas
[2]all of Texas

Another amphibian that has caused considerable ecological impacts is the bullfrog (*Rana catesbeiana*). Originally native to eastern North America, the bullfrog has been widely introduced in the western United States where it has been implicated (Rosen and Schwalbe 1995) in the decline of native ranid frogs and the Mexican garter snake (*Thamnophis eques*).

One reptilian invader of note is the brown tree snake (*Boiga irregularis*). Originally native to eastern North America, the bull-grog has been widely introduced in the western United States where it has been inmplicated (Rosen and Schwalbe 1995) in the decline of native ranid frogs and the Mexican garter snake (*Thamnophis eques*).

One reptilian invader of note is the brown tree snake (*Boiga irregularis*). Originally native to the New Guinea area, the brown tree snake was introduced to Guam, previously a snake-free island, around 1950 in a shipment of military cargo. An abundance of prey and in the absence of natural enemies, the brown tree snake spread throughout the island, reaching population densities that probably exceeded 100 snakes/hectare. Following the loss of native forest birds and drastic declines in the abundance of other vertebrates, brown tree snake populations fell to about 20-50 snakes/hectare. The coincidence of the arrival and proliferation of brown tree snakes on Guam and the loss of most of the island's indigenous forest vertebrates strongly support the snake's predatory role in the extirpation of many birds (Fritts and Rodda 1995). In addition to concerns

about native species, brown tree snakes also disrupt electrical power when they short out electrical systems, pose human health risks due to their venomous nature, and prey on domesticated animals.

Guam serves as a stark reminder of the potential impact of the brown tree snake on other tropical islands where it might be accidentally introduced as a result of commerce. If (when?) the snake becomes established in the Hawaiian Islands; it is likely to have disastrous effects on native forest birds. Hawaii has a rich but declining endemic fauna that is already under great stress. At least 35 species of birds, present on the islands at the arrival of the Polynesians around 400 A.D., became extinct prior to the arrival of Europeans in the late 1700s. Since then, another 16 species have vanished (Pyle 1995). In both eras, native birds were victims of habitat destruction, over-harvesting, introduced predators (Vitousek et al. 1987) including mongooses (*Herpestes javanicus*), pigs (*Sus* spp.), dogs (*Canis* spp.), and rats (*Rattus* spp.). More recently, the introduction of avian disease has had a negative impact on native birds (Jacobi and Atkinson 1995; Pyle 1995). Of the surviving species, at least 30 are listed as threatened or endangered under the provisions of the Endangered Species Act (Fritts and Rodda 1995).

The arrival of stowaway snakes has already been documented in Hawaii, the Marianas Islands and several other snake-free islands in the Pacific. The endemic and indigenous fauna of these islands is in grave peril if the brown tree snake establishes additional breeding populations.

Another reptile that has been introduced throughout the temperate and tropical parts of the globe is the slider turtle (*Trachemys scripta*). Once enormously popular in the United States as pets, millions were sold until the Food and Drug Administration banned the sale of turtles under four inches because they transmitted the disease salmonellosis. The pet trade then shifted overseas and now, 3-4 million are exported annually to Europe and Asia. Breeding populations have been established in Japan, Germany, Israel, South Africa and even the Mariana Islands (Ernst et al. 1994). In several of these areas sliders are considered pests that compete with native aquatic turtles.

Birds

Birds have been translocated around the world for many reasons. Some such as the cattle egret (*Bubulcus ibis*) were originally introduced from Africa to Hawaii for pest control. Others were intentionally introduced by acclimatization societies (groups that introduced plants and animals from their homeland) to establish populations of familiar birds in regions newly colonized by homesick human settlers. Many upland game birds and waterfowl have been introduced by sportsmen (Robbins 1995).

Some of the best known and most highly successful birds introduced into North America are the European Starling (*Sturnus vulgaris*), the House Sparrow (*Passer domesticus*) and the Rock Dove (*Columba livia*), all natives of the Old World. In the 1890s a resident of New York City decided that all the birds mentioned in the works of Shakespeare should be introduced into the United States (Hunter 1996). The Starling was mentioned by Shakespeare only once in *King Henry* IV, Part 1, but that was reason enough to establish a small breeding population of the species that now numbers more than 200 million and ranges across the continent to Alaska. Starlings are considered as pests because of their intense competition for nesting cavities and the associated detrimental effect on native cavity-nesting birds (Cabe 1993).

Some areas have avifaunas that are dominated by introduced birds. In Hawaii, at least 92 species have been introduced at one time or another and 54 species are considered to be established today. Of the latter, 57% were introduced more than 60 years ago and 43% were brought over since 1933 (Pyle 1995). Puerto Rico has about 20 species of exotic birds, far outnumbering the endemic species (Robbins 1995). At least 212 bird species have been introduced by humans to various parts of the world (Ebenhard 1988).

Mammals

Domesticated mammals including cows, sheep, goats, dogs, and cats are common and well-known examples of species that have often been introduced by humans into areas where they did not occur historically. Although they clearly benefit humans and facilitated our shift from hunter gatherer to more sedentary agrarians, they can cause great ecological damage when they establish feral populations.

Perhaps no better example can be found than the feral horses and burros of the western United States. These equids have thrived under federal protection provided by the Wild and Free-Roaming Horses and Burros Act of 1971 and upwards of 40,000 horses roam almost 43 million acres of public and private land in the

western United States. The average annual growth rate of horse populations ranges from 5-25% (Pogacnik 1995). With increasing herd sizes comes increasing concern of their impact on and land habitats (Loope et al. 1988), also utilized by native ungulates including deer (*Odocoileus* spp.), pronghorn antelope (*Antilocapra americana*) and bighorn sheep (*Ovis canadensis*).

Another interesting example of exotic mammal introductions gone awry was demonstrated when Russians released red foxes (*Vulpes vulpes*) and arctic foxes (*Alopex lagopus*) on previously fox-free islands in the Aleutian Chain of Alaska. Foxes were stocked starting in 1750 for fur farming. By the 1930s, over 450 islands had been stocked. A concurrent drastic decline in nesting seabird populations was observed as early as 1811 and populations of Aleutian Canada Geese (*Branta canadensis leucopareia*) were eliminated on all but three small islands (Bailey 1993), both probable results of fox predation.

In keeping with the fact that many species become noxious pests outside of their normal distributions, some species of North American mammals have become nuisances overseas. The gray squirrel (*Sciurus carolinensis*) and the mink (*Mustela vison*) are considered to be invasive species in the British Isles (Usher 1986).

Costs and consequences of invasive animal species

According to the report by U.S. Congress (1993) introduced exotic animals caused over 94 billion dollars of damage in the United States during the period from 1906-1991 (Table 3). This is a conservative estimate as only 14% of the non-indigenous species known to have harmful effects in the United States were included. Additionally, health costs, such as those attributed to stings by exotic fire ants (*Solenopsis* spp.) and Africanized honey bees (*Apis* spp.), would clearly increase the estimate.

Table 3.
Costs of exotic animal species from 1906-1991 (U.S. Congress 1993). Estimates are cumulative losses.

Group	Millions of dollars, 1991
Terrestrial vertebrates	225
Insects	92,658
Fish	467
Aquatic invertebrates	1,207

It is difficult to predict the impact of introduced exotic species on the environment. Ebenhard (1988) provided a thorough review of the ecological effects of introduced birds and mammals. Introduction of various mammals resulted in a plant or habitat effect through herbivory in 20% of all cases reviewed (n=788 introductions). Ecological impacts through predation were observed in 16% of 118 species introduced. In contrast, introduced birds were unimportant as herbivores and predators in their new ecosystems. Other impacts of invasive animals include competition, hybridization with native species, and the spread of diseases and parasites (Scanlon 1989). A more detailed discussion of the ecological impacts of invasive species is given by Vitousek (1990).

Conclusion

History has shown repeatedly that introduction of exotic species into areas that they did not occupy in historical times can, and often does, have dramatic impacts on native ecosystems. Some species were introduced with the best of intentions: mosquito fish for control of malaria and other human diseases, and cane toads and mongooses for the control of economically devastating agricultural pests. Others, like zebra mussels, were introduced accidentally. The key is whether or not we will learn from these mistakes.

Ironically, exotic animals can have beneficial impacts by controlling other exotics. Grass carp (*Ctenopharyngodon idella*) are highly effective at removing unwanted exotic vegetation such as *Hydrilla* from aquatic systems. However, the fish's effect on desired aquatic vegetation can be disastrous when unchecked. Production and controlled release of sterile triploid grass carp is an effective way to control vegetation without establishing breeding populations of the carp (Clugston and Shireman 1987; Bain 1993). Similarly, the

common carp (*Cypinus carpio*), a native of the Old World, has recently been shown to eat highly invasive zebra mussels (*Dreissena polymorpha*) in the Mississippi River (Tucker 1995). However, native species such as the turtle *Graptemys geographica*, also eat the mussel (Serrouya et al. 1995).

In the final analysis, many introduced animals have caused enormous harm both ecologically and economically. Given this track record, and the difficulty of predicting the impacts of exotic species, it is absolutely necessary to prevent further accidental releases and the introduction of unwanted species. Animals that are perceived to have potentially beneficial effects should be released only after rigorous testing under quarantine.

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