Rev. sci. tech. Off. int. Epiz., 2010, **29** (1), 19-22

Introduction

Invasive species
Part 1: general aspects and biodiversity
Part 2: concrete examples

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The problem of invasive species is of interest to researchers in a variety of different fields, including biology, epidemiology, agriculture, public health and even human sciences. It is an issue that affects all regions of the world to a greater or lesser extent (1, 2). It can also have detrimental effects on animal health and biodiversity. For example, the International Union for the Conservation of Nature (IUCN) reported that 625 (51%) of known endangered species are threatened because of invasive (alien) species (5).

The IUCN has established lists of species according to their level of vulnerability, as follows:
– extinct (EX)
– extinct in the wild (EW)
– critically endangered (CR) (the IUCN red list)
– endangered (EN)
– vulnerable (VU)
– lower risk (LR)
– data deficient (DD).

Many of these species are threatened by invasive species, but also by the international trade in endangered animals, plants and their products. In an attempt to protect these animals from the negative impact of this trade, 175 countries have signed the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

It must be remembered, as exemplified in many of the contributions to this thematic issue of the OIE *Scientific and Technical Review* (the *Review*), that the most invasive species is ours, human beings. Human beings are, and always have been, the cause of many animal and plant invasions, if not most.

By February 2007, the DAISIE project (Delivering Alien Invasive Species Inventories for Europe [3]), which was the joint effort of 83 partners and 99 collaborators, had identified 10,771 alien species in the region, belonging to fungi, bryophytes and lichens; vascular plants; terrestrial invertebrates; invertebrates and fish in European inland waters; marine biota; birds; amphibians and reptiles; and mammals. Of course, not all alien species have the same impact on animal health or biodiversity, but the sheer number of species reported is impressive.

The first contribution in this issue is devoted to the definition of an invasive species in order to try to clarify the situation from the beginning (7). Nevertheless, due to the lack of a clear common definition, each author was free to choose the most appropriate definition for their own purposes.

As exemplified in many of the articles in this issue, the mechanisms of invasion, either natural or deliberate, are many and have a long history. However, globalisation, with its 5 Ts – transport, trade, travel, tourism and terrorism – has dramatically increased the rhythm and the success of invasions. Climatic changes or other changes in the natural environment, such as forest encroachment, may also have an increasing impact.

The success of invasion will also depend on the biology of the invasive species and its capacity to adapt to a new environment. Moreover, natural invasions usually involve species that are able to travel easily, such as birds and bats. In Australia, for example, apart from several native rodent species and other eutherian mammals introduced by man (6), the only non-marsupial mammals are bats.

As stated above, the problem of invasive species is clearly linked to the issue of biodiversity. There is still much that is not known about the biodiversity of the planet, but we do know that there are currently 62,275 identified vertebrate species, as follows (8):
- 9,723 bird species
- 9,002 reptile species
- 5,416 mammal species
- 6,570 amphibian species
- 31,564 fish species.

The first complete inventory of mammal species was taken in 1982 and included 4,170 species. The last complete inventory was taken in 2005 and included 5,416 species (molecular taxonomic revision). The present estimate is that 99% of mammal species have already been identified. This increase in number seems to be paradoxical and even contradictory if one takes into account the extinction of some species during the same period. However, the reason for the increase becomes clear when one considers that each phenotype of newly discovered species is listed separately and, more importantly, that the advent of molecular technology allows for increasingly detailed comparisons of species limits and evolutionary relationships and the discrimination of species according to their genotypes.

Among mammal species there are 2,277 rodent species pertaining to 481 genera (42% of recognised mammal species) and 1,116 species of chiroptera (bats) pertaining to 202 genera (20.6% of recognised mammal species) (10). Bats are often the source of new emerging infections.

The number of identified virus species is approximately 5,000, but the actual number could well exceed 150,000, and viruses are evolving constantly.

There are already numerous examples of the negative effect that invasive species can have on biodiversity: the impact of the introduction of the red fox (*Vulpes vulpes*) on the native species in Australia, the impact of the invasion of the grey squirrel (*Sciurus carolinensis*) on the indigenous red squirrel (*Sciurus vulgaris*) in the United Kingdom, and the impact of the invasion by the American mink (*Mustela vison*) on the population of the European species (*Mustela lutreola*). Many other examples could be cited.

One must also consider the biodiversity of domestic species, especially livestock. Livestock ('stock of lives') have always played a crucial role in the subsistence of humankind, through meat, milk, eggs, honey, fibre and manure. Through selection, humans have created a huge number of different breeds of domestic animals, e.g. there are approximately 700 recognised breeds of cattle worldwide (4), but many of these are on the verge of extinction and have fewer than 100 breeding cows left. There is therefore a swift erosion of genetic variability in cattle that is very worrying, because genetic variability is the key to adaptating to a changing world, and, more widely, to evolution.

There are approximately 300 recognised dog breeds (more than enough to meet the needs of human beings for working dogs and companion animals). These breeds show a remarkable phenotypic and genotypic variability and this variability will be very useful in the area of genomics in finding the genetic basis of some human and animal diseases. The genome sequence of the horse has been obtained recently, which also offers many insights for some human genetic diseases (9).

Given that there are so many breeds of dog it is difficult to understand the present fashion for new exotic companion animals, for which the veterinary profession has no science-based knowledge and which may dramatically impact on the biodiversity of already fragile native species or introduce new emerging pathogens. Introduced domestic species may also have detrimental effects on native species, such as the impact of the introduction of goats, dogs and cats into the highly fragile and emblematic ecosystem of the Galapagos Islands.

The phenomenon of biological invasion is increasing, principally as a result of human activity. Human impact on the environment is often a contentious issue but we have tried to avoid excessive positions, which are often more ideological than rational, and instead provide a balanced picture of the current situation.

The areas of zoological expertise covered in this issue are numerous. A multidisciplinary approach was therefore needed, and we have sought the input of a range of authors, all experts in their fields. The topics covered by the different articles sometimes overlap and the examples given come from similar situations, but each author takes a different approach and provides new information, and the result is a more complete picture of the topics discussed. The invasion of alien species and the consequences of these invasions are often difficult to foresee, and exchanging experiences, both successes and failures, is highly valuable.

At a time in which many global changes are taking place (both climate-related changes and those even more directly linked to human activities, such as forest encroachment), we should keep as much variability as possible in all ecosystems, either natural or modified. This variability is key for evolution and adaptation, both within communities and within species, be they wild or domestic. Maintaining variability may be one of the best chances animal species have of surviving the dramatic changes in their environments that may occur.

As co-ordinators, we sincerely thank all the contributors to this timely thematic issue of the OIE *Review*. A special thanks to Prof. Frank Fenner, who gave us a personal account of his experience of the introduction of the European rabbit into Australia.

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