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This paper describes the ecological and economic consequences of introduced bird and mammal species for fauna, flora and habitats, for forestry and agriculture and also for other parts of the land developed and cultivated by man. The results presented are based on enquiries to various institutions for the environment, nature conservation, agriculture, forestry and game as well as on the analysis of scientific data from various sources including the author's. Allochthonous bird and mammal species occurring in Germany are mentioned. Examples of interspecific competition for resources between allochthonous and autochthonous species, of changes to habitats by exotic species, of interbreeding and of the introduction of diseases and parasites are given. Economic damage to agricultural crops, to fruit-growing, viniculture, forestry, parks and to inshore waters is outlined. Bird species mentioned include the ring-necked parakeet *Psittacula krameri*, Canada goose *Branta canadensis*, swan goose *Anser cygnoides*, pheasant *Phasianus colchicus*. Mammal species covered include the muskrat *Ondatra zibethicus*, nutria *Myocastor coypus*, rabbit *Oryctolagus cuniculus*, raccoon *Procyon lotor*, raccoon dog *Nyctereutes procyonoïdes*, mouflon *Ovis musimon*, fallow deer *Dama dama* and sika deer *Cervus nippon*.

Key words: introduction, exotic wildlife, birds, mammals, ecological effects, economic damage

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Man dominates ecosystem earth profoundly affecting all organisms inhabiting the planet. As with plants, animal species, animal populations, communities and also animal dispersal are influenced directly and indirectly in various ways. Active dispersal of animals is achieved by means of swimming, flying and walking; passive dispersal includes transport by water currents, wind, animals and transport by man.

Passive expansion of an animal's distribution area caused by man may be deliberate or unintentional. In this connection Niethammer (1963) distinguishes between passive dispersal, defined as an unintentional transport of animals across former distribution boundaries, and introduction which refers to the deliberate import of alien animals. Introductions may occur with the intent to establish wild populations, e.g. of game species. Exotic animals are also imported as pets to be kept in wildlife enclosures, in zoos and in a variety of private hobby-farms, and to be used in commercial breeding programmes. From there these animals get into the wild either through releases or escapes (Niethammer 1963, Nowak 1981, Streit 1991). Sometimes such animals trigger ecological and economic problems.

Methods

Enquiries made to the state ministries of agriculture and the environment, to offices of the Nature Conservancy Agency, to hunting associations, and analysis of reports and relevant literature form the basis for the statements made in the following. Personal observations and results that I obtained, such as conclusions drawn from the analysis of the results of the status colloquium 'Neozoans - new animal species in nature' in Fellbach (near Stuttgart, Southern Germany) on 9-10 May 1995 (which I co-chaired together with S. Schmidt-Fischer) and the results of the ensuing ad hoc work group 'Neozoans' (Gebhardt et al. 1996), also contributed to the total data base.

Results

Examples of bird and mammal species introduced into Germany are shown in Table 1 and 2. The species listed include animals which have unintentionally reached Central Europe including present-day Germany such as house mouse *Mus musculus*, ship rat *Rattus rattus*, Norway rat *Rattus norvegicus* and species which were deliberately introduced such as the pheasant *Phasianus colchicus*, turkey *Meleagris gallopavo*, rabbit *Oryctolagus cuniculus*, mouflon *Ovis musimon* and sika deer *Cervus nippon*. Of the species listed, the Bennett's or red-necked wallaby *Macropus rufogriseus* stands out. After 1887, several attempts were made in various part of Germany to establish the animal. However, by 1920 the Bennett's wallaby had disappeared from Germany, in part due to hunting and poaching. Other species have either reached Germany by means of natural dispersal following introduction into another country (raccoon dog *Nyctereutes procyonoïdes* into the western part of the former USSR), as escapees (American mink *Mustela vison*, nutria *Myocastor coypus*) or their introduction is the result of a combination of releases into the wild and escapes from captivity (ring-necked parakeet *Psittacula krameri*, raccoon *Procyon lotor*, muskrat *Ondatra zibethicus*). In addition, animal species establishing local populations after release from captivity by their former owner, are spotted regularly in the wild, e.g. Siberian chipmunk *Tamias sibiricus*.

Records of released or escaped animals of species such as golden hamsters *Mesocricetus* spp. in settlement areas have been disregarded as populations generally do not survive through the winter. The most unusual finding was the discovery of a female skunk *Mephitis mephitis* with litter near Freiburg (Southern Germany) in 1994 (M. Braun & U. Kerkhof, pers. comm.).

Ecological consequences to the ecosystem

In the following, the effect of the introduction of exotic bird and mammal species on existing biocoenosis is described. The data has been arranged to conform with the system proposed by Ebenhard (1988).

The effect of herbivory and predation on native flora and fauna

Introduced mammal and bird species may contribute to changes in the native fauna and flora by various means, e.g. depletion of resources and alteration or destruction of habitats. Based on a complex system of response, avoidance and defence mechanisms, a finely tuned ecological

Table 1. Examples of introduced bird species in Germany, including species which cause ecological[1] and/or economic damage[2] (data sources: Niethammer 1963, Nowak 1981, Hölzinger 1987, Rheinwald 1993, Bezzel 1985, 1996, U. Mahler, pers. comm.).

Species	Time of introduction	Origin	Success
Chilean flamingo *Phoenicopterus chilensis*	Early 1980	S-America	One single population
Black swan *Cygnus atratus*	1963	Australia	Locally few breeding pairs
Swan goose [1] *Anser cygnoides*	?	Asia	Locally few breeding pairs
Canada goose [1, 2] *Branta canadensis*	ca 1955	N-America	Established
Egyptian goose *Alopochen aegyptiaca*	18th century	Africa	Locally small populations
Ruddy shelduck *Tadorna ferruginea*	ca 1960	Africa	Regionally few breeding pairs
Wood duck *Aix sponsa*	ca 1888/90	N-America	Regionally few breeding pairs
Mandarin [1] *Aix galericulata*	ca 1900	E-Asia	Locally small populations
Bobwhite *Colinus virgianus*	1872	N-America	Locally small (short-lived) populations
Pheasant [2] *Phasianus colchicus*	ca AD. 0	Asia	Established
Turkey *Meleagris gallopavo*	ca 16th century	N-America Central America	Locally small populations
Ring-necked parakeet [1] *Psittacula krameri*	ca 1970	Africa, Asia	Locally established
Green parakeet [1] *Myiopsitta monachus*	1892	S-America	Locally established

balance exists among native species. Exotic species however, do not dovetail into this intricate structure.

Introduced bird species such as the Canada goose *Branta canadensis* may damage vegetation along shorelines and in shallow water. Most notably emersed and submersed macrophytes, e.g. reed and all *Potamogeton* species, are affected. This is especially the case if population numbers are kept high due to supportive feeding while vegetation cover is low or regressing (Ostendorp 1993, Bezzel 1996, pers. survey results). Heavy grazing on aquatic plants may also result in the destruction of spawning habitat of phytophilic fish species, e.g. rudd *Scardinius erythrophthalmus*, carp *Cyprinus carpio*, tench *Tinca tinca*. These fish species depend on vegetation as substrate for the deposit of their spawn (Gebhardt 1990). In addition, insect species requiring emersed aquatic plants to deposit their eggs, are also adversely affected by such alteration of the habitat. Furthermore, the birds' faeces cause eutrophication of small water bodies, resulting in lower water quality which in turn will result in lower species diversity among fish, amphibians and aquatic invertebrates (Grosch 1978, Bauer et al. 1993, Ostendorp 1993).

The effect of the introduction of the muskrat will be discussed as representative of the more serious mammal invaders. The muskrat, an animal native to North America, lives along the edge of water bodies and in the reeds. It immigrated into Germany from a location near Prague, the Czech Republic, around 1914/15 and quickly spread across the country. Today the muskrat is found throughout most of Germany. The animal only failed to establish itself in parts of the country lacking perennial water bodies or in rocky terrain. The fact that the muskrat was able to occupy the vacant ecological niche between the water vole *Arvicola terrestris* and the beaver *Castor fiber* is part of the reason for the animal's great success in expanding its distribution area. Foraging on aquatic plants and on vegetation lining the shore and using the same vegetative matter to construct its floating nest, the animal causes large-scale destruction of reed beds. On the positive side, this results in areas of open water providing habitat for floating-leafed plants and various waterfowl species. The downside is that breeding areas of some bird species dependent on dense reed beds are destroyed. Insects, fish and amphibian species living or breeding among the reed are also affected negatively. In addition,

Table 2. Examples of introduced mammal species in Germany, including species which cause ecological[1] and/or economic effects[2] (adapted and expanded after Streit 1991; data sources: Niethammer 1963, Nowak & Paradiso 1983, Niethammer & Krapp 1982, 1986, 1993, M. Braun, pers. comm.).

Species	Time of introduction	Origin	Success
House mouse [2] *Mus musculus*	Neolithic	N-Africa, S-Europe, E-Asia	Established
Ship rat [1, 2] *Rattus rattus*	Antiquity	SE-Asia	Established
Norway rat [1, 2] *Rattus norvegicus*	Middle Ages ? 18th century ?	E-Asia	Established
European rabbit [2] *Oryctolagus cuniculus*	12th century ?	Spain, N-Africa	Established
Muskrat [1, 2] *Ondatra zibethicus*	1914/15	N-America	Established
Nutria [1, 2] *Myocastor coypus*	ca 1930	S-America	Regionally established
American mink [1] *Mustela vison*	ca 1930	N-America	Regionally large populations
Siberian chipmunk *Tamias sibiricus*	ca 1969	Japan, Korea	Locally established
Bennet's wallaby *Macropus rufogriseus*	1887-1910	SE-Australia	All populations extinct by 1920
Raccoon *Procyon lotor*	1930	N-America	Regionally established
Raccoon dog *Nyctereutes procyonoides*	1960	E-Asia	Regionally established
Mouflon [2] *Ovis musimon*	Neolithic ? 1902	Corsica, Sardinia	Regionally established
Sika deer [1, 2] *Cervus nippon*	1928	E-Asia	Local populations
Fallow deer [1, 2] *Dama dama*	3rd-4th century ?	Asia Minor	Regionally established

the muskrat exerts substantial predation pressure on freshwater mussel populations. There is evidence that local destruction of populations of the mussel *Unio crassus*, a species classified as endangered in Germany, was triggered by muskrat predation. The economic problems of burrowing activities are described later.

Impairment of native fauna through competition

The ring-necked parakeet, an animal native to Africa and Southern Asia, is one of a number of exotic birds impairing German fauna (introduced ca 1970). It is the most successful of several parrot species occurring in Germany today. Populations centre around public parks and botanical and zoological gardens. In several German cities (e.g. Wiesbaden, Heidelberg and Cologne), sightings of free-living ring-necked parakeets including nesting animals go back as far as the late 1960s/early 1970s. Meanwhile there is a multitude of reports from a number of cities and further expansion must be expected (Zingel 1993, Bezzel 1996). The species is cold-resistant and able to utilise a wide variety of vegetable food. The birds have even been known to visit landfills, and in their search for something edible the birds may even utilise various vegetable parts - from waste disposal sites (G. Groh, pers. comm., Zingel 1993). As a result of their adjustment to new food sources and as the birds display great aggressiveness when defending a nest hole, ring-necked parakeets compete successfully with native hole-breeders. With regard to the resource 'nest site', the animal easily displaces native species dependent on holes for breeding or shelter. These include bats *Myotis* spp., fat dormouse *Glis glis*, garden dormouse *Eliomys quercinus*, titmice *Parus* spp. and woodpeckers *Dryobates* spp., excluding the black woodpecker *Dryocopus martius* (G. Groh, pers. comm).

The sika deer originates from East Asia. It was introduced into Germany in 1928. Although occurring only locally, total population has increased remarkably (Eisfeld & Fischer 1996). This put autochthonous herbivores, especially the red deer *Cervus elaphus*, under mounting pressure. This results in the sika deer displacing the red deer by being a superior competitor for resources. A survey I conducted showed that the sika deer is more resilient toward changes in its environment and is not as easily disturbed by human activity. Thus, the sika deer has a major advantage over the red deer when it comes to feedings areas and daytime shelter.

Introduction of diseases and parasites

On numerous occasions, import of exotic animal species has resulted in concurrent introduction of new diseases, parasites and 'pests' in the broader sense. Well documented cases are known especially for fish parasites, insect crop and forest pests (Amlacher 1981, Franz & Krieg 1982).

The liver fluke *Fascioloides magna* was introduced into Europe with the wapiti *Cervus elaphus canadensis* and white-tailed deer *Odocoileus virginianus*. Natural hosts are deer species of the genera *Odocoileus* and *Cervus*; intermediate hosts are snails of the genera *Lymnaea*. The liver fluke spread quickly across Europe and, especially in the former Czechoslovakia, Italy and Germany caused substantial losses in populations of roe deer *Capreolus capreolus*, red deer and fallow deer. The parasite was also transmitted to livestock (ruminants) (Frey & Kutzer 1981, Boch & Schneidawind 1988).

Boye (1996) with reference to Schwarz & Heidemann (1994) describes another example of transmission of a disease among mammals with devastating consequences. Presumably as a result of overfishing in the Arctic ocean and hence caused by man, the harp seal *Phoca groenlandica* found its way into the North Sea. The harp seal carried the distemper virus against which the common seal *Phoca vitulina* was not resistant. Starting in 1988, common seal populations crashed. In total, 18,400 seals succumbed to the disease; but by now, populations have recovered.

Until now, the introduction into Europe of alien bird species has not resulted in the introduction of any diseases or parasites (E. Bezzel, pers. comm.).

Changes to the gene pool through hybridisation

The genetic identity of autochthonous populations is lost when introduced species interbreed with their native ecological counterpart. Permeated in such a manner, this may lead to the disappearance of autochthonous populations, and thus must be seen as a diminution of biodiversity.

In Germany, there is a growing number of reports of geese hybrids, especially from water bodies in or near settlements. For instance, the Canada goose, a bird of North American origin, crossbreeds with the native greylag goose *Anser anser*. Furthermore, hybrids of the greylag goose and the swan goose *Anser cygnoides* have been observed (Wüst 1970, Herkenrath 1993, Meyer 1995).

Interbreeding may also be a problem among mammals, e.g. for sika deer and red deer. According to Eisfeld & Fischer (1996) the sika deer represents a threat to the autochthonous red deer, as the two species crossbreed. As an example they cite mixed populations of sika and red deer in Ireland which emerged after the sika deer was introduced on the island (Harrington 1973). Thus, sika deer are a permanent menace to neighbouring red deer populations.

Economic consequences

There are numerous examples from all around the world of introduced animal species becoming a problem in agriculture, forestry and fisheries either as competitors or as pests. A survey conducted in Germany brought the following results:

Only a small percentage of the mammal species introduced and but a few alien bird species cause economic damage. Among birds, the introduced Canada goose deserves special attention. Particularly in Northern Germany, the bird, joining forces with native and northern goose species, is responsible for grazing damage and trampling of fields (winter crop, rape) and green areas. According to estimates by farmers, agricultural associations and state ministries of agriculture damages amount to ca DEM 1-3 million annually (pers. survey in the states). Damages are most severe if the top soil has thawed as grazing will remove or strongly injure the roots of the plants under these conditions. Yet, if the top soil is frozen, damages to winter crops may be compensated in the ensuing growing period even if 60-100% of the area under cultivation was stripped clean. This is confirmed by data from the Upper Rhine Valley (U. Mahler, pers. comm.). However, it must be emphasised that the flocks of geese, counting thousands of individual birds, that descend on winter crop fields mostly consist of native species and winter guests (greylag goose, white-fronted goose *Anser albifrons*, brent goose *Branta bernicla*, bean goose *Anser fabalis*). Only a relatively small percentage of the birds are Canada geese. In addition, Canada geese together with native goose species are responsible for considerable overgrazing and dirtying (faeces) of waterside meadows and green spaces as well as park ponds and water bodies used for swimming.

The pheasant was introduced as a game bird. When populations are high, the animal can be a pest in plantations. Feeding on seed and seedlings in corn fields it causes considerable damage at times. Furthermore, the bird has been known to cause notable harm to vegetable fields and vineyards in some areas. In total, damages amount to ca DEM 2.5 million per annum (BBA 1978, BMELF 1991).

Economic damage caused by introduced mammal species varies: For instance, so far the import of raccoon and raccoon dog did not affect small game as badly as feared. Enquiries made to various institutions of the German states show that small game populations have not suffered due to the introduction of these two species.

However, the introduction of mouflon, fallow deer and sika deer resulted in an increase of game damage in forestry and agriculture. The damage to young hardwood trees due to browsing and debarking is a cause for concern. The loss in yield in agricultural fields due to grazing also poses a problem.

Regionally, rabbits cause great damage by grazing on cereal crops and by browsing in beet fields, vegetable fields, vineyards, orchards, tree nurseries, forest plantations and in urban parks. In addition, by burrowing they damage levees, dykes, embankments, urban parks, and also runways on airfields. In total, damages amounted to more than DEM 10 million per annum (BBA 1978). Today the costs will be even higher.

The muskrat represents another serious problem. The animal is in the process of expanding its range in Germany. State-employed muskrat hunters have caught the animal in great numbers in Germany in recent years (1983: 336.706, 1984: 240.878, 1993: 340.467, 1994: 308.400; data source: BMELF, unpubl.). By burrowing they destabilise embankments, levees and dykes. During times of flooding or due to additional strain exerted by such means as vehicular movement, this results in collapse of banks and occasionally in breached dykes. Compared with that, damage to agricultural fields (cereal crops, rape, beet) due to grazing is relatively small. Damages caused by burrowing are difficult to estimate as this includes direct structural damages as well as resultant damages (e.g. flood water intrusion after a breach in a dyke); annual toll amounts to many million German marks.

Nutria and muskrat occupy similar habitats and the damage they cause is alike in kind. However, as the former is not nearly as widespread in Germany, the overall damage caused by nutria is significantly smaller than the damage caused by muskrat.

Conclusion

Worldwide biodiversity is endangered by loss of species (extinction) and habitat destruction. Another problem is the worldwide homogenisation of the flora and fauna by introduction of allochthonous species (Kinzelbach 1995). However, while the effect of introduced bird and mammal species on Europe's native flora and fauna has not yet been investigated (Gebhardt et al. 1996), Temple (1992) established for North America that the introduction of exotic bird species is a major threat to the native American avifauna.

The number of introduced bird and mammal species in Germany is not very large. Yet, among them are species causing ecological and/or economic concern. Thus, critical evaluation of these animals is necessary. As proposed by Ebenhard (1988) the various effects of allochthonous species on their environment can be classified into four categories, i.e. interspecific aggression and competition for resources (e.g. ring-necked parakeet/ native hole-breeders, Canada goose/native geese), interbreeding between allochthonous and autochthonous species (e.g. sika deer/ red deer), changes to the habitat (e.g. muskrat, nutria) and introduction of diseases and parasites (e.g. liver fluke

Fascoloides magna). Articles by various authors deal with this (e.g. Harrington 1973, Akkermann 1975, Boch & Schneidawind 1988, Herkenrath 1993, Ostendorp 1993, Zingel 1993, Lohmann 1995, Boye 1996, Eisfeld & Fischer 1996). Also the realisation of nature conservation objectives, like protection of endangered species and important habitats, may be encumbered by introduced species (e.g. muskrat). Economic consequences of the introduction of exotic bird and mammal species include, among other things, damage to agriculture and forestry, parks, green areas, inshore waters, embankments, dykes and roadways (BBA 1978, BMELF 1991, Rheinwald 1993). These effects have occurred in other countries also (Nowak & Paradiso 1983). Resultant costs and hazards to people due to breaches in dykes and road damage must be regarded as particularly serious and demand countermeasures. Consequently, ecological and economic consequences of the introduction of exotic wildlife is undeniable.

Imported animal species do not necessarily affect the autochthonous fauna as negatively as is often feared. For instance, when the raccoon was introduced into Germany there was much fear that the animal would cause great damage to the avifauna and small game species. No such thing happened so far. The same is true for the raccoon dog (Röben 1975, Niethammer & Krapp 1993, Lutz 1996). However, this may be due in part to low population numbers. However, individual species can cause serious problems. Thus, it is necessary to translate into action the resolutions of the convention signed in Rio de Janeiro in 1992 regarding allochthonous species. According to this, the introduction of allochthonous species that pose a threat to ecosystems has to be prevented and the species have to be controlled or removed (BMU 1992). The necessary guidelines have not yet been formulated for allochthonous bird and mammals species. However, they may be adapted from existing guidelines for other animal groups (e.g. aquatic organisms, Tiews 1986, EIFAC 1988). A major objective in this context must be the development of a global standard.

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