

Eradications of invasive alien species in Europe: a review

Piero Genovesi

Chair European Section IUCN SSC Invasive Species Specialist Group, National Wildlife Institute, Via Ca' Fornacetta 9, 40064 Ozzano, Emilia (BO), Italy (e-mail: infspapk@iperbole.bologna.it; fax: +39-051-796628)

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Abstract

Eradication of alien species is a key conservation tool to mitigate the impacts caused by biologic invasions. The aim of the present paper is to review the eradications successfully completed in Europe and to discuss the main limits to a wider application of this management option in the region. On the basis of the available literature – including conference proceedings, national reports to the Bern Convention, etc. – a total of 37 eradication programmes have been recorded. Thirty-three eradications were carried out on islands and four on the mainland. The rat (*Rattus* spp.) has been the most common target ($n = 25$, 67%), followed by the rabbit ($n = 4$). In many cases, these eradications determined a significant recovery of native biodiversity. Differently to other regions of the world, no eradications of alien invertebrates and marine organisms have been recorded; regarding invasive alien plants, it appears that only some very localized removals have been completed so far in Europe. The limited number of eradications carried out in Europe so far is probably due to the limited awareness of the public and the decision makers, the inadequacy of the legal framework, and the scarcity of resources. Synthetic guidelines for improving the ability of European states to respond to aliens incursions are presented.

Introduction

Eradication of alien species is globally acknowledged as a key management option for mitigating the impacts caused by biological invasions (e.g., Wittenberg and Cock 2001; Genovesi and Shine 2003). The Convention on Biological Diversity (CBD) calls for a hierarchical approach, primarily based on the prevention of unwanted introductions, but considering eradication as the best alternative when prevention fails (guiding principles adopted in 2002 with Decision VI/23). Article 11 of the Bern Convention (which has almost all European states as its members) calls parties to strictly control the introduction of invasive alien species, and the standing committee of this convention has approved many recommendations urging parties to activate eradications of intro-

duced species. Also, the Global Strategy for Plant Conservation, adopted by the CBD Conference of the Parties in 2002, urges parties to eradicate some major alien species that threaten plants, plant communities and associated habitats and ecosystems.

Many invasive alien species have been eradicated worldwide, managing in this way to prevent the impacts they cause to biological diversity, economy and human well being (Simberloff 2002). In recent years, eradications have become a routine management tool especially on islands, where many introduced vertebrates have been successfully removed: for example, in New Zealand, 156 eradications have been completed (D. Veitch, pers. comm.); in northwestern Mexico, eradications have been carried out from 23 islands since 1995 (Tershy et al.

2002); in West Australia, mammal eradications have been completed on 48 islands since 1969 (Burbridge and Morris 2002). Most of these eradications have involved vertebrates, but there are also examples of successful eradications of plants (Rejmanek and Pitcairn 2002) and invertebrates, including fruit flies from Nauru (Allwood et al. 2002) and *Anopheles gambiae* from over 30,000 km² of Brazil in the 1950s (Davis and Garcia 1989). Even marine organisms have been eradicated in some cases (when invasion was still localized) as a Mussel (*Mytilopsis* sp.) introduced in Cullen Bay (Australia) (Bax et al. 2002) and a sabellid polychaete (*Terebrasabella heterouncinata*) successfully removed from a mariculture facility in California (Galil 2002).

Successful eradications have brought very significant effects in terms of recovery of native biological diversity. Focusing on Europe, the eradication of rats from the islands of the Mediterranean has been proven to determine the recovery of many colonial nesting seabirds as the storm petrel (*Hydrobates pelagicus*) and the Cory's shearwater (*Calonectris diomedea*) (Martín et al. 2000), but also of several terrestrial bird species such as the dunnock (*Prunella modularis*), the wren (*Troglodytes troglodytes*) and the rock pipit (*Anthus petrosus*) (Kerbiriou et al. 2004). In an analysis of the consequences of the black rat (*Rattus rattus*) introduction in the Mediterranean, Martín et al. (2000) concluded that the elimination of rats from medium-sized Mediterranean islands may be particularly efficient in recovering several bird species, some of which are highly threatened.

Surprisingly, despite removal techniques having been greatly improved, Europe has a particularly solid technical and scientific background, and there are large areas (e.g., Mediterranean islands, Macaronesian archipelagos, etc.) where this management option may be very helpful in the recovery of threatened species and ecosystems – the eradication of alien species appears to be still only occasionally considered for conservation in Europe. For example, in the proceedings of a recent international conference on eradication of island invasives, there was only one European contribution reporting a failed attempt to eradicate *Spartina anglica* from some estuarine areas of Northern Ireland (Hammond and Cooper 2002).

In order to assess the diffusion of eradication programmes in Europe and the main limiting factors to a wider application of this management option, the present paper reviews all the known cases of eradications of alien species of plants and animals successfully completed in the region.

Methods

This review intends to cover all cases of eradications, defined as the complete and permanent removal of all wild populations of a species from a defined area by means of a time-limited campaign (Genovesi 2000; modified from Bomford and O'Brien 1995). The above definition is considered in an extended way, including the cases of removal of few individuals, because I did not want to exclude the cases when an introduced species was detected early after its arrival and immediately removed. This, in fact, is the best response to an introduction, although such a large definition may risk to create some overlap between the eradication of a few individuals (e.g., removal of a few beavers in France or of a few individuals of domestic cats from an island, both cases included in the review) and the simple capture of individuals after escape from captivity (not included in the review).

The information on eradications is particularly difficult to collect, because it is scattered, often available only in grey literature, if it is published at all (Simberloff 2002). For the present review, I firstly checked the scientific publications, focusing in particular on the proceedings of conferences and workshops held in recent years on the issue of alien species (e.g., in 1999, the Council of Europe organized in Malta the first European workshop specifically focused on the eradication of terrestrial alien species). Another important source of information has been the reports prepared by parties of the Council of Europe to the Bern Convention secretariat. In fact, as said above, the Bern Convention Standing Committee has approved several recommendations (rec. 18 (1989); rec. 45 (1995); rec. 57 (1997); rec. 61 (1997); rec. 78 (1999); rec. 77 (1999); etc) urging parties to eradicate alien species threatening native biodiversity; to respond to these recommendations, many European countries have established national reports illustrating the activi-

ties carried out in their territories on this specific management option. In order to facilitate the collection of these national reports, the Council of Europe has also organized several meetings of experts in invasive alien species, and the proceedings of these workshops have also been extensively analysed for the review. Lastly, much information has been obtained directly by specialists, managers and NGOs.

Results

A total of 37 eradication programs successfully completed in Europe have been recorded (Table 1). These include the successful removal of the coypu and the muskrat from Great Britain, of rats, goats, rabbits and American minks from several small islands of the Macaronesia, Mediterranean, Brittany, Britain and the Baltic sea. Thirty-three eradications were carried out on islands and four on the mainland (muskrat, coypu and a small population of Indian porcupines from the British isles; the Canadian beaver from France). The rat (*Rattus* spp.) has been the most common target ($n = 25$, 67%), followed by the rabbit ($n = 4$). Almost all eradications realized in Europe (apart from the muskrat and the coypu) were started for conservation purposes; in 12 cases, the programmes were co-funded by the European Union through LIFE programmes. Most eradications were carried out after the 1980s ($n = 31$; 84%), and in recent years, the number of projects is rapidly increasing.

In some cases, the eradications reported have involved very few animals (e.g., cats from Alegranza, where only two animals were killed; 12 porcupines from Devon); very likely there have been many more cases than those reported in which a few individuals that arrived at some areas were rapidly removed.

I did not record any eradication of alien invertebrates and marine organisms. Although some local eradications of invasive plants have been carried out (for example in Great Britain by Plantlife International), I did not find information on these cases on the sources I accessed for the review. Apart from a few local cases (i.e. virtual eradication of Australian swamp stonecrop *Crassula helmsii* from a pond in Gerrard's Cross – Buckinghamshire – by using a glyphosate-based

compound over 2 years; A. Miller, unpubl. report), I think it can be said that no larger eradication of alien plants has been ever successfully carried out in Europe so far.

Discussion

The list of eradications presented here is far from being comprehensive, as I probably failed to collect information on several small scale removals of alien plants and animals. However, the general picture that comes out from this review is probably correct. In Europe, only a very limited number of eradications have been successfully completed so far, and these do not include any invertebrate, plant or marine organisms. Europe, despite its long tradition of nature conservation, its solid scientific background and the large availability of funds in respect to other geographical regions, is in this specific field of action far behind other and less developed areas of the world.

The small number of eradications carried out in Europe is due to several reasons. For example, in the attempted eradication of the grey squirrel in Italy, the failure of the programme was mainly due to the inadequate legal basis (in most European states, alien species are often automatically protected by national laws), the scarce awareness, the unclear line of authority, and the opposition of radical animal rights groups (Genovesi and Bertolino 2001; Bertolino and Genovesi 2003). In the famous case of the *Caulerpa taxifolia* (Meinesz 1999), a decision on whether to start an eradication or not was delayed for long, partly because of an academic controversy, partly because of the unclear repartition of roles. The removal of the rabbit from a small island of the Canary was suspended when it was almost completed, because the project ran out of funds; a re-start of the eradication has now been approved, but the suspension has totally defeated the results obtained in the first campaign, when the population was almost completely removed (Martín 2002; A. Martín, pers. comm.). Legal inadequacy and scarce resources are indicated as the major constraints to the possibility to eradicate *Spartina anglica* from Northern Ireland estuaries (Hammond and Cooper 2002).

Table 1. Sources: (1) Gosling and Baker 1989; (2) J. Hughes, pers. comm.; (3) Zonfrillo 2002; (4) Smallshire and Davey 1989; (5) Macdonald et al. 2002; (6) Pascal 1999; (7) Kerbirou et al. 2004; (8) M. Pascal, pers. comm.; (9) Rouland 1985; (10) Perfetti and Sposimo 2001; (11) Perfetti et al. 2001; (12) Oliveira 1999; (13) Pitta Groz 2002; (14) Jimenez 1994; (15) Martín 2002; (16) A. Martín, pers. comm.; (17) J.L. Rodriguez-Luengo, pers. comm.; (18) J. Mayol, pers. comm.; (19) Orueta, in preparation.

Country	Region	Archipelago	Island	Area (ha)	Species	Estimated population size	Eradication year	Source
Great Britain	Pertshire, Sussex			~100,000	<i>Ondatra zibethicus</i>		1935	1
	Wales		Puffin	32	<i>Rattus norvegicus</i>		1998	2
	Scotland		Handa	363	<i>Rattus norvegicus</i>		1997	2
	Scotland		Ailsa Craig	104	<i>Rattus norvegicus</i>		1990	2, 3
	Wales		Ramsey	253	<i>Rattus norvegicus</i>		2000	2
	West Anglia				<i>Myocastor coypus</i>	6000	1981	1
	Devon				<i>Hystrix brachyura</i>	12	1980	4
Estonia	Baltic		Hiiumaa	~100,000	<i>Mustela vison</i>	50	1998	5
France	Brittany	Sept Ile	Rouzic	3	<i>Rattus norvegicus</i>		1951	6
	Brittany	Sept Ile	Bono	22	<i>Rattus norvegicus</i>	700	1994	6
	Brittany	Sept Ile	aux Moines	9	<i>Rattus norvegicus</i>	200	1994	6
	Brittany	Sept Ile	Plate	5	<i>Rattus norvegicus</i>	100	1994	6
	Brittany	Sept Ile	aux Rats	0	<i>Rattus norvegicus</i>	20	1994	6
	Brittany	Rimains	Rimains	2	<i>Rattus norvegicus</i>	100	1994	6
	Brittany	Rimains	Chatellier	1	<i>Rattus norvegicus</i>	50	1994	6
	Brittany	Rimains	Rocher de Cancale	0	<i>Rattus norvegicus</i>	10	1994	6
	Brittany	Molène	Trielen	15	<i>Rattus norvegicus</i>	150	1996	6, 7
	Brittany	Molène	Enez ar C'hriazienn	1	<i>Rattus norvegicus</i>	30	1996	6
	Brittany	Houat	aux Chevaux	3	<i>Rattus norvegicus</i>		2002	8
	Brittany	Tomé	Tomé	30	<i>Rattus norvegicus</i>		2002	8
	Corsica		Lavezzi	110	<i>Rattus rattus</i>		2000	8
St. Fargeau				<i>Castor canadensis</i>	24	1985	9	
Italy	Tuscany	Tuscan	Legemini (1)	10	<i>Rattus rattus</i>		1999	10, 11
	Tuscany	Tuscan	Legemini (2)	10	<i>Rattus rattus</i>		2000	10, 11
	Tuscany	Tuscan	Scoglio La Peraiola	10	<i>Rattus rattus</i>		2000	10, 11
	Tuscany	Tuscan	dei Topi	10	<i>Rattus rattus</i>		2000	10, 11
	Tuscany	Tuscan	d'Ercole	10	<i>Rattus rattus</i>		2000	10, 11
	Tuscany	Tuscan	La Scola	2	<i>Rattus rattus</i>		2001	10, 11
	Portugal	Macaronesia	Madeira	Deserta grande	1421	<i>Oryctolagus cuniculus</i>		1998
Macaronesia	Azores	Praia Islet	11	<i>Oryctolagus cuniculus</i>	100–200	1997	13	
Spain	Columbretes		Isla Grossa	14	<i>Oryctolagus cuniculus</i>	175	1993	14
	Macaronesia	Canary	Montana Clara	130	<i>Oryctolagus cuniculus</i>	127	2001	15
	Macaronesia		Lobos	430	<i>Felis catus</i>	4	2001	16, 17
	Macaronesia		Alegranza	1020	<i>Felis catus</i>	2	2002	16, 17
	Mediterranean	Balearic	Dragonera	280	<i>Capra hircus</i>		1975	18
	Mediterranean		Conills	1	<i>Rattus rattus</i>	>100	1999	18
	Mediterranean	Chafarines	Ray Francisco	12	<i>Rattus rattus</i>	ca. 50/ha	2000	19

The lack of concern, awareness and public support to the removal of vertebrates seems more diffuse in Europe than in other regions of the world. Apart from the grey squirrel case in Italy, several goat eradication projects have been stopped by public opposition (e.g., in the Parco

Naturale di Portofino, Italy); public opposition is likely the main reason why only one goat eradication has been completed so far. Even in the case of the Coypu, the removal of a population recently introduced in a small lake in Sicily was strongly opposed by the local branch of the

WWF, and never started. Also, a proposal to eradicate the hedgehog (*Erinaceus europeus*) from Uist (Western Islands, Scotland), where the species causes impact on several bird species by egg predation, has been rejected for the ethical opposition to the control techniques.

Another problem is the limited ability to detect new invasions early and to rapidly respond to these. Although large scale eradications are scientifically and technically challenging, the best cases of eradication are those carried out rapidly after the arrival of a new species, before it starts to spread (e.g., Rouland 1985). In Italy, we recently discovered a population of Asian squirrels (*Callosciurus* sp.) in Maratea, a small tourist town on the southern coast of Italy; the squirrels have probably been introduced over 30 years ago, and in this time lapse, no local or national service (forest service, game departments, etc.) managed to detect the species; only in late 2002, when the population became very abundant causing increasing problems to trees and cables, the presence was reported to the National Wildlife Institute, when it was probably too late to remove them (G. Aloise et al., in preparation).

Despite the various problems highlighted here, there are several examples of very effective actions carried out in Europe. The eradication of the coypu from West Anglia is one of the largest and the most complex eradications ever realized in the world; its success was made possible by a science-based planning of the removal, adequate funding and the approval of a specific legislation. The eradication of the Himalayan porcupine from Devon required ca. €230,000 for removing 12 animals only (costs actualized to year 2000), but likely prevented much more severe economic losses to crops in the long term (Smallshire and Davey 1989). The ongoing eradication of the ruddy duck (*Oxyura jamaicensis*) from the Palearctic, is indeed the most ambitious eradication ever planned for conservation purposes, as it requires a complex coordination and cooperation scheme among many different countries, where the main control efforts need to be concentrated in a country (Great Britain), that is not the area where the impacts are recorded (hybridization with the white headed duck, *O. leucocephala*, occurs in the Iberian peninsula) (Hughes et al. 1999); furthermore, the control of the ruddy duck (a beautiful ornamental duck) in Great Britain

shows that it is possible to effectively address the opposition of the public, provided a solid effort and commitment by both the academic world and the non-profit organisations are made.

In conclusion, on the basis of the information on eradication summarized in the present paper, the main lesson that we can learn is that in Europe, more than elsewhere, we urgently need to revise our policies to ensure early detection and rapid response to new incursions, with an increased ability to eradicate at least the most threatening alien species. The key elements for such a revision of national policies have been recently reviewed by Genovesi and Shine (2003) and include the following:

- Promote education and public awareness programmes to engage local communities and appropriate sector groups in eradication; encourage their participation.
- Review national legislation to ensure that the legal status of alien species is compatible with mitigation measures.
- Streamline the authorization process for rapid response; consider the use of emergency orders where urgent eradication action is needed; equip competent authorities with powers to take appropriate mitigation measures.
- Establish procedures to collect, analyse and circulate information of alien species, including identification keys for different taxonomic groups.
- Set up early warning systems, focusing especially on key areas.
- Prepare contingency plans for eradicating specific taxa (e.g., plants, invertebrates, marine organisms, fresh-water organisms, fresh-water fishes, reptiles, amphibians, birds, small mammals, large mammals).
- Provide adequate funds and equipment for rapid response to new invasions and train relevant staff to use the eradication methods selected.
- Prepare and implement, providing adequate funds and support, eradication plans for some major alien species.

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