Guidelines for Eradication of Terrestrial Vertebrates: a European Contribution to the Invasive Alien Species Issue

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INTRODUCTION

Invasive alien species (IAS) are now acknowledged as one of the major threats to biodiversity, together with habitat loss and fragmentation. Furthermore, it is predicted that biotic invasions will become the major engines of ecological disintegration in the future; this is because of the increased spread of alien species, due to the greater mobility of the human population, rapidly growing transport technology, expanding tourism and travel activities, and world-wide free trade (Cox 1999, Ruesink et al. 1995).

In addition to the threats to biodiversity, the direct costs of IAS are immense. It is difficult to estimate precisely the economic losses caused by biotic invasions, including the impact of weeds on crop production, the increased costs of control, the decreased water supply, the management costs of reducing the alterations of protected areas, the impact of introduced pathogens affecting wildlife and public health, and the impact of marine organisms transported by ballast waters. However, the costs likely exceed tens of billions of Euros annually (GISP 2000).Therefore, the planning of more effective strategies to deal with biotic invasions is a conservation priority on a global scale. For this purpose, the implementation of new actions at a national, trans-border and international level are required, based on a proactive rather than reactive approach.

The need to prevent and control introductions and the severe threats posed by biotic invasions have been repeatedly addressed at an international and regional level (see Shine *et al*. 2000 for a review).

In the last decade, the World Conservation Union (IUCN) also made invasive species a primary focus for its global action; the Species Survival Commission, supported by the Invasive Species Specialist Group, recently produced the "Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species" (IUCN 2000). Furthermore, the IUCN is a major partner of the Global Invasive Species Project (GISP), a coalition of scientists, economists, lawyers, social scientists, conservation and resource managers working together since 1997 to develop a new comprehensive strategy, that will lay the groundwork for new tools in science, education and policy through collaborative international actions. According to decision V.8 of the last COP of the Convention of Biological Diversity (CBD), the GISP will assist the Executive Secretary in the implementation of art. 8(h) (see Box 1).

The general concern of conservationists about the threats posed by biological invasions, and the general acknowledgement of the need and urgency to define and implement actions to reduce these threats, are faced with several obstacles. The major difficulty concerns the complex scientific, technical and political aspects involved, which include the sources of invasions, the pathways and modes of entry, the economic and emotional aims of intentional introductions, the methods to detect

new invasions, the control techniques and their public acceptability, etc. In order to deal with biotic invasions, it is fundamental to address very different aspects, including international trade regulations, control during transport, border controls and quarantine, detection of new propagules, and public perception of the control methods. Furthermore, the generally very limited awareness of this threat by the public and decision-makers leads to inadequate participation and political commitment. IAS are a cross-cutting issue, which requires the co-ordination and commitment of several different sectors, as well as close co-operation between ministries with different responsibilities.

In synthesis, the key words for dealing with biotic invasions are: prevention, awareness and control. The purpose of the present report is to address the latter aspect, defining tools for eradicating invasive alien species once they are introduced into a new ecosystem. Nevertheless, it must be clear that control can only be effective if included in a coherent and comprehensive strategy. Biotic invasions represent the major challenge for conservation in the new millennium, requiring a holistic approach based on the efforts of governments, politicians, scientists and managers.

The European level: activities carried out under the Bern Convention

The Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, 1979), with its 44 Contracting Parties in Europe, represents a powerful means to promote co-operation at the European level and in general to seek solutions to the threats posed by biotic invasions. Article 11 Paragraph 2.b of the convention refers to alien species: each Contracting Party has to undertake to strictly control the introduction of non-native species. The convention also includes other related provisions: Article 6, paragraph e, prohibits the internal trade of animals listed in Appendix II to the Convention; Article 7, paragraph 3, sub-paragraph c, deals with the regulation of transport of wild animals; Article 9, paragraph 1, fourth indent, refers to derogations permitted for purposes of re-population and re-introduction. Furthermore, the Standing Committee, which is responsible for overseeing the application of the Bern Convention, approved several recommendations suggesting procedures to reduce threats posed by invasive species, including:

- No. 18, adopted in 1989, on the protection of indigenous crayfish in Europe;
- No. 45, adopted in 1995, on controlling proliferation of *Caulerpa taxifolia* in the Mediterranean;
- No. 57, adopted on 5 December 1997, on the introduction of organisms belonging to non-native species into the environment, requested Contracting Parties to prohibit such introductions;
- No. 61, on the conservation of the white-headed duck (*Oxyura leucocephala*), noting the main threat to the long-term survival of the white-headed duck caused by the risk of hybridisation with the North American ruddy duck (*O. jamaicensis*), requested Contracting Parties and observer states to develop and implement without further delay national control programmes, which could involve eradication of the ruddy duck from all countries in the Western Palaearctic.
- No. 77, adopted on 2 December 1999, on the eradication of non-native terrestrial vertebrates;
- No. 78, adopted on 2 December 1999, on the conservation of the Red Squirrel (*Sciurus vulgaris*) in Italy, urged Italy to eradicate the invasive American Grey Squirrel (*S. carolinensis*).Since 1991, the Council of Europe, operating the secretariat of the Bern Convention, has made several efforts to support member states in the implementation of Article 11, Paragraph 2.b. In particular:
- In 1992 a Group of Experts on legal aspects of the introduction and re-introduction of wildlife species was set up. This Group met on three occasions to review the legislation of Contracting Parties concerning this issue; a first report on Legal Aspects of the Introduction and Re-introduction of Wildlife species in Europe was published in 1992 (Isabelle Trinquelle T-PVS (92) 7). A second study on “Introductions of non-native organisms into the natural environment” was published 1996 (Cyrille de Klemm. Nature and Environment Series 73);

the purpose of this study was to review the state of international law and of the national legislation of European countries concerning introductions, re-introductions and restocking and to present proposals aimed at strengthening national control mechanisms and enhancing the role of the Standing Committee.

- In 1997 a report on "Introduction of non-native plant species into the Natural environment" by Jacques Lambinon, was published in Nature and Environment series No 87
- In March 1998, the Bern Convention commissioned a report on "Methods to Control and Eradicate Non-Native Terrestrial Vertebrate Species", compiled by Orueta and Ramos, which thoroughly analysed the methods for controlling and eradicating non-native terrestrial vertebrates, discussing their reliability, efficiency, selectivity and humanness in respect to the different taxonomic groups.
- In 1999, the Bern Convention organised a workshop on the eradication of terrestrial vertebrates (Malta, June 3-9), where the experiences gained in Europe on such eradications were synthesised, circulated and discussed.
- In relation to recommendation no. 61, the Bern Convention in 1999 promoted a study on "The Status of the Ruddy Duck (*Oxyura jamaicensis*) in the Western Palaearctic and an action plan for eradication, 1999-2002" (T-PVS/Birds (99) 9).

Scope of the present report

Despite the remarkable efforts to provide instruments for best management of invasive alien species, at present the implementation of eradication campaigns remains inhomogeneous at the European level. In some cases, the reasons for the gap between the available instruments and their concrete application include the deficiency of national strategies in some countries, limited public acceptance, and the often unclear decision lines.

The aim of the present paper is to help reducing these obstacles. In view of the need to integrate eradication campaigns into global and regional strategies on IAS, the report is organised in two parts. In the first part, the guiding principles for dealing with biotic invasions are reviewed, especially with respect to the planning of eradications. In the second part, guidelines for planning an effective eradication campaign are defined. With respect to the very comprehensive report by Orueta and Ramos (1998), which contains an up-to-date review of the available control methods, the present report will focus on the different aspects of the correct and effective planning of a control campaign, including biosecurity policies, repartition of roles and responsibilities, monitoring needs, and recovery of native species after eradication.

Taxa considered

Patterns of arrival, establishment and spread of alien species, as well as methods for detecting new propagules and for controlling them, differ greatly among the main functional biological groups; in this regard, it was decided to focus the present report on terrestrial vertebrates which, although numerically negligible with respect to weeds and invertebrates, represent a major threat to several ecosystems.

Examples of such a threat are also reported in the annex to the recommendation no. 77 of the Bern Convention, where several cases of terrestrial vertebrates threatening European biodiversity are listed. They include: the risk of extinction of the white-headed duck, threatened by the introduced ruddy duck through hybridisation, the risk of extinction of the red squirrel (*Sciurus vulgaris*) through competition with the introduced American grey squirrel (*S. carolinensis*), the severe impact of the American mink (*Mustela vison*) through predation on both ground nesting birds and the water vole (*Arvicola terrestris*), and through competition with the endangered European mink (*Mustela lutreola*); the alteration of many vulnerable wetland ecosystems caused by the coypu (*Myocastor coypus*).

Furthermore, many European island ecosystems are particularly vulnerable to IAS, as confirmed by the impact of predation on nesting birds by introduced rats in many Mediterranean islands or by overgrazing by feral goats and rabbits. Rat, goat, rabbit and mink control programs carried out on several islands have proved to be extremely successful means to restore native biodiversity (see Boxes 4 and 5); priority should be given to the promotion of similar programs in the future.

The limited scope of the present report should not be interpreted as an under-evaluation of the impacts caused by non-vertebrate IAS. Invaders are present in all *taxa*, and definition of specific management tools to address invasions by all animal and plant groups is needed and should represent a follow up of the present work.

Coherence with other international guidelines

In view of the need for unequivocal terminology, coherent policies and co-operation among parties, particular attention has been paid to other guidelines developed at an international level. In particular, the terminology has been partly derived from the IUCN "Guidelines for the Prevention of Biodiversity Loss caused by Alien Invasive Species".

The general principles have also been defined on the basis of the IUCN guidelines and of the GISP strategy, as synthesised in the Global Strategy for Addressing the Problem Of Invasive Alien Species, presented at the GISP synthesis meeting in Cape Town, 17-23 September 2000.

Finally, in the discussion of the technical aspects, the indications provided by the Toolkit of Best Prevention and Management Practices, prepared by Wittenberg and Cock within the framework of the GISP, have been thoroughly considered.

Definitions

In the present report the following definitions of terms will be adopted:

"Invasive Alien Species" (IAS) means an alien species, subspecies or lower *taxon* which becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity.

"Alien species" (non-native, non-indigenous, foreign, exotic) (AS) means a species, subspecies or lower *taxon* occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce (IUCN 2000).

"Biosecurity threats" means those matters or activities which, individually or collectively, may constitute a biological risk to the ecological welfare or to the well-being of humans, animals or plants of a country (IUCN 2000).

"Intentional introduction" means an introduction made deliberately by humans, involving the purposeful movement of a species outside of its natural range and dispersal potential. (Such introductions may be authorised or unauthorised.) (IUCN 2000).

"Introduction" means the movement, by human agency, of a species, subspecies or lower *taxon* (including any part, gametes or propagule that might survive and subsequently reproduce) outside its natural range (past or present). This movement can be either within a country or between countries (IUCN 2000).

"Native species" (indigenous) means a species, subspecies or lower *taxon*, occurring within its natural range (past or present) and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans.) (IUCN 2000).

"Natural ecosystem" means an ecosystem not perceptibly altered by humans (IUCN 2000).

"Unintentional introduction" means an unintended introduction made as a result of a species utilising humans or human delivery systems as vectors for dispersal outside its natural range (IUCN 2000).

"Eradication" complete and permanent removal of all wild populations of a species from a defined area by means of a time-limited campaign (Bomford and O'Brien 1995, modified).

"Control" reduction of population density and abundance, in order to keep damage at an acceptable level.

"C**ontainment"** limiting the spread of a species by containing its presence within defined geographical boundaries (Bomford and O'Brien 1995).

GUIDING PRINCIPLES FOR A EUROPEAN STRATEGY TO ADDRESS INVASIVE ALIEN SPECIES

The threat posed by biotic invasions must be addressed through an holistic approach, based on awareness by the public and decision makers, prevention of new introductions, containment and effective control of new IAS once prevention has failed to block their arrival.

The eradication of IAS is an important, but not completely sufficient, element of such an approach. For this reason, before the different aspects that need to be considered when planning and implementing an eradication program are described, the context of biosecurity policies, actions, repartition of roles and responsibilities will be discussed.

First of all, it must be recognised that several countries (notably New Zealand, Australia, USA and several island states) have begun to implement organic biosecurity policies, managing in some cases to markedly reduce threats posed by IAS. Europe lacks a regional strategy and a common policy on the issue, although it has opportunities for the implementation of a comprehensive strategy. Several bodies and institutions (UE, Bern Convention, and other relevant bodies) can facilitate the discussion, approval and implementation of a common policy. Furthermore, it should be noted that some European countries have a particularly solid background for the development of strategies based on a scientific approach.

Prevention

Prevention of the arrival of new IAS is the most effective and least costly management strategy to reduce threats posed by biotic invasions, and it should always be the first line of defence. As a principle, no alien species should enter a country - either intentionally or accidentally - unless authorised after an appropriate Risk Assessment procedure.

Target

Conservation requires prevention of the arrival, or control, of species which threaten biodiversity or human well-being (IAS). Moreover, IAS represent only a small proportion of the total number of alien species. Nevertheless, our limited ability to predict the invasiveness of a species (Gilpin 1990, Lodge 1993), makes it necessary to prevent the arrival of all aliens, unless they are proven to be harmless (cf. *precautionary principle*).

Awareness at the source

Efforts should be concentrated on the prevention of new introductions already at their place of origin. The intentional and/or accidental transport of living organisms can be limited by means of increased education, awareness and information, directed especially towards tourists, transport operators and trade organisations.

Major invasive pathways

Alien species arrive via very different pathways. An analysis of the pathways of introduction can allow efficient control during transport. In this regard it is important to distinguish between the initial entry into a country (or region) and a later natural spread. Natural expansion of an alien species established somewhere else is particularly critical because: 1) it means that the ecological conditions are suitable to the establishment, 2) it may be more difficult to contain the natural spread of a species than to prevent its introduction. Risk assessment for entire pathways may be more effective than for single species.

Border control

Border control is potentially the most effective way to prevent intentional and unintentional introductions of invasive species (e.g. rats), but it requires a complex framework of rules, trained staff and reference lists.

Precautionary principle

Although it is possible to predict some general characteristics of the epidemiology of biotic invasions, this is true only in a very general statistical sense. The long term impact of a new invader, or its future expansion patterns, can only be predicted with a high level of uncertainty.

Therefore, a precautionary approach should be followed when dealing with new alien species. The precautionary principle is well synthesised by the definition "guilty until proven innocent" (Ruesink *et al*. 1995). Such an approach introduces the principle that the introduction of alien species should be prohibited unless authorised, and links authorisation to a risk assessment procedure.

Black, grey, white lists – Risk assessment

In order to allow an effective filter to the intentional introduction of invasive species, a three-list system should be implemented, based on a 1) "black list": species whose importation is prohibited; 2) "grey list": importation allowed only after an assessment of risks. 3) "white list": species evaluated by a risk assessment, classified at low risk and whose importation is allowed in general, or under conditions restricting the use of the species to specific purposes (research, public education, others), or only after the holding facilities to contain the animals have been inspected and approved.

"White lists" should be developed at a national or sub-national level, and all species included in them should have undergone a risk assessment. Any species not yet known to be harmful or harmless is included in the grey list. An authorisation to import should always require a risk assessment, which is a management tool aimed at predicting, on the basis of current knowledge, the actual risks related to introductions. The purpose is generally to provide scientific information, so that decisions can be made in a thorough, consistent, logical and transparent way.

An important aspect of risk assessment is the environmental impact assessment, aimed at predicting potential threats to biodiversity and the environment. Potential adverse effects of an introduction to the environment, and the probability of these effects occurring, can be assessed by analysing the intrinsic characteristics of the species, the ecological relationships in its original range, and the similarities between its original range and the introduction area. A more detailed description of the parameters that should be considered in a risk assessment procedure is provided in a later chapter.

The three-lists system is comprehensive, because all species fall into one or the other list (most species are included in the grey list, which is not a real list), and it should be dynamic, i.e. it should permit the shift from one list to the other if new information becomes available. For example, where risk assessment shows that a species is low risk or beneficial, the entry into the country can be authorised and the species can be included on the white list.

When a species is authorised for entry into a country after risk assessment, and importations occur for a long period, the risk should be reassessed periodically since the environment may change and new information about the species may become available.

A potential option to reduce costs related to the three-lists system is that anyone applying for authorisation to import a species included in the "grey list" should be responsible for producing a risk assessment.

The authorisation process should explicitly cover all imports into the country, including import for maintenance in captivity, since accidental escapes from captivity are one of the most common causes of invasions of terrestrial vertebrates.

Management of introduced alien species

Prevention can reduce new introductions, either accidental or intentional, but cannot halt them. When an alien species has been detected, i.e. when prevention has not been successful, it follows from the precautionary principle that an eradication program should always be considered first. In fact, eradication is the most coherent solution in terms of biodiversity conservation and is more effective, cost effective and ethical than other management alternatives such as control, containment and do-nothing.

Eradication is a difficult and often extremely expensive management tool and careful assessment of cost effectiveness should precede its use. Nevertheless, when a rapid response is ensured and adequate resources are devoted, eradications may be feasible, representing in these cases one of the most effective tools to protect and recover biodiversity.

Rapid action

Two factors limit the time period after which eradication of an invasive species becomes a non-preferable alternative: 1) feasibility (eradication may become impracticable once the invasive species reaches a certain population level and/or range expansion); 2) usefulness (the undesired effects caused by the invasive species become irreparable). In general terms, mainland eradications remain feasible for a critical period, whose duration is difficult, if not impossible, to predict with a high level of certainty. This factor accounts in part for the much higher proportion of successful eradications on islands than on mainland. Usefulness is difficult to define because of the limited capability to predict the long-term impacts of IAS.

Therefore, on the mainland, the rapid implementation of an eradication program is crucial. This means that it is important to set up mechanisms to ensure a rapid response: 1) early detection mechanisms, 2) a simple authorisation process, 3) a clear line of authority, and 4) availability of contingency funding (Myers *et al*. 2000). In this regard, the creation of national biosecurity agencies, formally delegated to remove alien species when detected, is a potentially efficient option.

Early detection

In view of the need for rapid action, early detection is a general requisite for the effective management of IAS. Early detection requires the circulation of information about alien species and the methods to monitor their presence. The Global Invasive Species Database, implemented by the IUCN Invasive Species Specialist Group, is available on the net (http://www.issg.org/database) currently as a prototype. It could be a fundamental tool to effectively circulate information on IAS, their ecology and means of control.

Monitoring efforts should be concentrated on high-risk entry points (airports, harbours, train stations), the surroundings of places of captivity (breeding farms, zoological gardens, game parks, etc.), and key high-value biodiversity areas.

Moreover, the creation of biosecurity agencies, with the mandate to constantly monitor new introductions, may constitute an important step toward reducing the time needed to detect new propagules of alien species. Also public education can be an important element for speeding up detection.

Prevention of new introductions

A successful eradication program is only feasible when the immigration rate of the alien species being eradicated is zero, i.e. a new invasion of the management area must be prevented. Therefore, when the removal of an IAS is planned, the means to prevent future re-invasions should be carefully addressed.

Contingency plans

Concerning the risk of re-invasion, it is also advisable to develop contingency plans and funding for the rapid removal of new propagules, in case the IAS is detected in the future.

Legislation

The ability to take appropriate measures against intentionally or unintentionally introduced alien invasive species needs to be based on stringent legislation. In accordance with the precautionary principle, legislation should define a clear authorisation procedure for the importation of alien species and for their release in the wild.

To discourage new illegal releases or escapes resulting from irresponsible maintenance, several principles should be investigated, including the Polluter Pays Principle, a bond system or the taxation of activities directly or indirectly causing invasions (transport, trade, tourism, breeding farms, etc).

International communication and co-operation

Communication and co-operation are critical to effectively deal with biotic invasions, since:

1. the prevention of new introductions requires the development of regulations for the trade and transport of living organisms, which can only be established through international negotiations and the development of new international treaties;
2. information on the invasiveness of an alien species in other invaded areas and on the control methods applied in the species' range can be particularly helpful;
3. the prevention of introduction via the natural expansion of already established invasive species requires communication among government agencies of different countries;
4. the eradication of transboundary populations requires the participation, or at least co-ordination, of neighbouring countries (e.g. ruddy duck Box 2, grey squirrel Box 3). Europe, which in part has a free trade system, needs to develop new tools to allow border controls and to promote regional communication and co-operation among States.

PLANNING AN ERADICATION

Eradication should not be attempted unless it is feasible, it does not cause unacceptable undesired effects, and re-invasions can be prevented. Planning an eradication should be based on science and the results should be circulated in order to promote a constant improvement of the techniques.

Selection of target species

The first step in a decision process is to decide which species to eradicate. The selection of the target species should be based on

1. time constraints for an eradication,
2. present and predicted impact of the species on biodiversity, health and economic activities,
3. feasibility of the eradication,
4. feasibility of restoration of the site once the IAS is removed.

Priority should be given to new propagules. The feasibility of an eradication is generally much higher before the species starts to expand. Since the time lag between the arrival of a species and its expansion is highly variable and almost impossible to predict, the best option is rapid action.

Second, priority should be given to species known or predicted to cause a significant impact on biodiversity or human well-being. The selection of species can result more rapid if a list of species proved to be harmful under similar conditions is available (see the Global Invasive Species Database in *Early detection*). In view of the critical time constraints of eradications, the development of "black

lists" (at an international, regional or national level) would be very effective in speeding up the decision process (e.g.: "Examples of invasive species which have proven to be a threat to the biological diversity", appendix to the recommendation n. 77, Bern Convention, 1999).

Concerning the reversibility of effects, high priority should be given to prevention of the early spread of species predicted to cause long-lasting or permanent effects, whereas after establishment in the wild, priority should be given to the eradication of species causing reversible impacts (Parker *et al*. 1999). In these cases, the recovery of native ecosystems after the eradication should be included in the planning.

The development of lists of priority, also based on "black lists" of species known to be harmful to biodiversity, can help speed up the decision process. In the absence of a "black list", risk assessment can be used to identify priority lists.

Risk assessment

Risk assessment can represent an important tool for best management, but the lack of scientific certainty about the implications of a potential biological alien invasion, and the resulting uncertainty of predictions (Parker *et al*. 1999), should not be used as a reason to postpone eradication. On the contrary, a precautionary principle should be adopted. For risk assessment, the following information should be collected and considered:

1. precedents of the species becoming invasive in other places,
2. probability of population increase and geographical spread,
3. possibility of interbreeding with native *taxa* and the related risk of genetic pollution,
4. sanitary risks for the release area,
5. other potential impacts on native species and ecosystems.

The probability of population increase and geographical spread can be assessed on the basis of information about the population dynamics, dispersal patterns, habitat requirements of the species and habitat conditions in the introduction area.

Risks posed to human health, well-being and economic activities should be thoroughly evaluated and the related costs estimated. The potential impacts to cultural values and ethics should also be taken into account.

Risks to strictly human related values, such as ethical or cultural values, are particularly difficult to assess in a scientific way; indeed, the perceived risk may be the only valid assessment (Warren in prep.). Although education and information can help reduce the inconsistency between objective and perceived risks, in some cases the decision needs to be made at a political level.

Since they are based on analyses of the ecological conditions of the introduction area, the results obtained from a risk assessment procedure should not be extrapolated to other biogeographical regions.

Feral and commensal species

Feral animals of domestic species (domestic cats, dogs, goats, etc.) and non-native commensal species (*Rattus* spp., *Mus* spp., etc.) can be some of the alien species most aggressive and damaging to the natural environment, especially on islands. Eradications of rats, goats, and cats constitute a major part of the eradications carried out globally and often lead to spectacular results in terms of biodiversity recovery (e.g. in Boxes 4 and 5).

Although strong public opposition to the control of pet species (especially the cat) can be expected, the removal of feral and commensal non-native species, when appropriate, should be considered a potentially effective management option.

Defining desired outcomes

A clear definition of the aims of the eradication is fundamental for a cost/benefit analysis, for coherent and organic planning of interventions and for evaluation of the success of the eradication. The risk of confusing general goals (protection of native biota) with means (control) should be avoided (Parkes 1990). Control of an alien species should be considered a tool to achieve the higher goal of ecosystem preservation or restoration.

When newly formed propagules are eradicated, on the basis of the precautionary principle the outcome is the prevention of potential impacts; thus, monitoring the response in the native species or ecosystems is not necessary. In contrast, when the eradication of an established IAS is planned, then the desired outcome in terms of recovery of native species, habitats or ecosystem functionality, or mitigation of impacts on human well-being, should be clearly identified. On the basis of the definition of the desired outcome, it is then important to identify appropriate measures of success and to adequately monitor these measures.

Assessing feasibility

Implementation of an eradication campaign should only be attempted if it is ecologically feasible and has the necessary public support and financial and political commitment to its completion. Thus, an assessment of an eradication's feasibility requires the evaluation of both ecological and socio-economic aspects. In the present chapter, ecological and socio-economic aspects will be treated separately, though they often overlap.

A common criticism of eradications is that they are very difficult, indeed almost impossible, to achieve once a species has become established in the wild (Bomford and O'Brien 1995). Nevertheless, it is important to underline that the key factor limiting the realisation of an eradication is generally the effort required, which may be excessive with respect to the available resources (Rainbolt and Coblentz 1997).

Despite the limited number of eradication programs carried out in Europe, the large number of successful removals achieved in other regions proves that they have good probability of success, at least when carried out in geographically isolated areas or on the larger species. For example, it is evident that the eradication of rats, rabbits, goats and other feral animals from many Mediterranean islands would be feasible.

Biological parameters

For the long-term success of an eradication campaign, removal efforts should be adequate to assure that the rate of removal exceeds the rate of increase at all population densities and that all individuals are vulnerable (Bomford ad O'Brien 1995). Thus, the eradication techniques should be defined on the basis of the best available information about the biological and ecological characteristics of the target species.

Biotic invasions can be dealt by means of an epidemiological approach: as with parasites or other pathogens, the vectors of the IAS, their minimum viable population size, time course and population growth, patterns of spread, the fate of interacting species (including their coevolution) and the effects of the new environment on the IAS, should all be considered (Mack *et al*. 2000).

Biological data

In the planning of an eradication program, the following information should be collected and analysed:

- The minimum viable population is a critical parameter for allowing the establishment of a species.
- The lag period (time lapse between the establishment of an IAS and its spread) is critical because chances of successful eradication are much higher before the species starts to expand.

- The dispersal pattern is generally considered the most important parameter affecting the feasibility of an eradication. High dispersal species (e.g. American mink) are generally more difficult to eradicate and are more likely to re-invade.
- The reproductive rate is the second most important ecological parameter to be considered. High reproductive rates reduce the chance of successful eradication.
- To ensure that all individuals are vulnerable to the eradication techniques, home range size and distribution should be considered, in order to define the density and distribution of removal items (traps, baits, etc.).
- Social behaviour affects the vulnerability to removal techniques; in particular, access to baits and traps can be restricted to dominant individuals, and trap happiness can vary between sex and age classes. Thus, the social organisation, trap-shyness and behavioural differences between sexes and ages should be considered.
- An understanding of seasonal variability in the vulnerability of the population to removal items can help to optimise the removal success.

Time needed for the eradication

The time needed for eradication can be estimated on the basis of a population census and the predicted removal rate. A trial eradication can be performed to collect the necessary information (removal success, removal selectivity, equal vulnerability within the population, etc.).

When no estimates of the target population are available and there are no strict constraints on the available resources, an adaptive approach can also be followed, i.e. with a preliminary phase and a constant revision of the campaign on the basis of the results obtained. For example, the plan for the eradication of the coypu from the UK was partly based on population simulations by means of post-mortem examinations of animals killed during preliminary control campaigns (Gosling and Baker 1987).

The continuity of the removal activities can also strongly affect the success of a campaign. In the eradication of goats from Raoul Island, the campaign went on for several years and the resulting decrease in goats numbers led to a regeneration of vegetation. However, the vegetation growth determined an increase of the goat reproductive rate, which shifted from 0.96 to 1.70 kids/female/year creating new obstacles to the eradication (Parkes 1990). Therefore, it is preferable to concentrate the removal efforts in time, rather than to apply a reduced effort for a longer period.

Density-dependent removal success

Density-dependent effects should be carefully addressed. Removal success may change significantly at low densities, and in some cases the use of combined techniques may be necessary , e.g. hunting and trapping to remove mammals from more than 12 Mexican islands (Donlan pers.comm.) and *myxoma* virus, poison, trapping, gassing and shooting to remove rabbits from Phillip Island (Coyne pers.comm.).

Effects of control on the demography of the target species

Effects of the control technique on the life history and demography of the target species should also be taken into account. Indeed, control measures may cause an increased population reproductive rate, as hypothesised for the coypu (Gosling *et al.* 1981), or affect the dispersal patterns, increasing the immigration and/or emigration rates. Despite the general lack of data on this aspect (Usher 1989), the potential effects of the control campaign on the reproductive rate of the remaining individuals and on the juvenile survival rate should be considered when predicting the effort and time needed for an eradication.

Other ecological effects of the control

Ecological changes induced by the control techniques may significantly affect the removal success (e.g. the introduction of pathologies and subsequent onset of resistance). A multiple techniques approach can be fundamental in some cases.

Unacceptable undesired effects

Another condition affecting the feasibility an eradication is that removal methods should not have unacceptable effects on biodiversity.

The potential killing of non-target species, the consequent impact on their populations, and disturbance to vulnerable species caused by operators should be considered. Before the campaign proceeds, an assessment must be made of the short-, medium- and long-term disadvantages of potential undesired effects. If a campaigns turns out to have detrimental impact on non-target species populations, the techniques should be revised (Usher 1989). Effects on individuals, including limited number of accidental deaths of non-target species and limited disturbance caused by the control, should be minimised if possible, but should not cause a suspension of the operation. However, it must be noted that it is common for species that might be detrimentally affected by an operation to benefit greatly from the removal of the target species.

Socio-economic parameters

Before starting an eradication program, the time, personnel, and budget needed to achieve the desired results should be carefully estimated, and the necessary resources should be raised. Risks of underestimation of the necessary efforts should be minimised, and contingencies should be included in the calculation. Indeed, it is advisable to use "worst case" simulations (e.g. Gosling and Baker 1987 for the coypu) to estimate the necessary removal efforts. With enough effort and resolution, eradication will be feasible in most cases. Insufficient effort devoted to eradications often represented a major cause of their failures (Rainbolt and Coblentz 1997, Usher 1989).

Time

A prediction of the time required to achieve the desired outcome is often fundamental in defining the required resources. Responsible organisations should ensure their commitment for the expected duration of the campaign, estimated through "worst case" simulations.

Personnel

Obviously, time and personnel are closely related. In the eradication of rats from Langara Island, it was decided to fit the eradication into a single summer season; 90 operators were considered necessary in relation to the total number of bait stations needed to accomplish the eradication (n=3,881) and the number of stations that could be checked daily by each operator (Kaiser et al. 1997). In the coypu eradication project, the required number of trappers was estimated with different simulations, and 20 operators were necessary to keep the population declining by about 20% per year (Gosling and Baker 1987). The maintenance of an adequate removal effort also at low densities is crucial.

Cost/benefit

Since a clear commitment is a pre-requisite for the start of an eradication program, cost estimates are a key element in the planning of an eradication. Nevertheless, estimating the cost of an eradication is often difficult, and the figures can change significantly according to which parameters are considered (e.g. Parkes 1990).

The costs of eradication should include expenses for public relations and public meetings when an involvement of the public is required (Myers *et al*. 2000).

Benefits of eradications are generally difficult to estimate, especially if the future impact of the IAS is difficult to predict (Myers *et al*. 2000, Parker *et al*. 1999). However, to allow a correct evaluation of the alternatives, the costs of the do-nothing strategy should also be calculated; for example, the high cost of the successful coypu eradication from Great Britain (2.5 million UK£, Gosling 1989) can be better evaluated if compared with the costs of the routine management (population control, damages to agriculture, etc.) of coypus in countries where the species has not been eradicated and is now widespread, such as France, Germany or Italy.

Chances of success

The chances of success of the eradication should be evaluated on the basis of the above parameters. For this purpose, the susceptibility to control techniques, the time needed for the eradication, and the available resources must be considered. Nevertheless, many biological parameters are only partly predictable and the chances of success also depend on the political commitment, availability of funds and public support. For these reasons, a fully reliable evaluation of the chances of success of an eradication is often very difficult: an adaptive approach can also be considered.

Organisation

A key requirement for a successful eradication is that the competencies, roles and responsibilities are clear and that the legal framework allows the competent bodies to take all necessary actions (Myers *et al.* 2000).

Competencies and roles

The best option for ensuring a rapid and effective implementation of an eradication program is to vest a single body with the competencies to carry on the different steps required: rapid warning, risk assessment, feasibility analysis and eradication. A clear definition of roles should be provided by the legal framework.

Responsibilities

The decision to start an eradication campaign is often a political decision, based on a cost/benefit evaluation of the biological, economic and human-dimension aspects. For small-scale eradications (e.g. newly formed propagules), the decision should be entrusted to the competent technical bodies (biosecurity agency).

Public involvement

Eradications often represent a controversial management practice, and in several cases opposition by the public or by specific interest groups have resulted in the failure of the project (e.g. Box 3, Genovesi and Bertolino *in press* a). Therefore, whenever possible and appropriate, decisions should be made after a consultation process.

Public involvement requires the considerations of some principles. First of all, effective participation must be allowed; for this purpose, adequate information must be provided to the public and the decision process should adequately consider the resulting comments (Warren in prep.). Transparency of the entire process is crucial to obtain the required public confidence in the campaign.

On the other hand, any decision should be made on the basis of relevant matters and on a clear distinction between real and perceived risks.

Finally, in view of the urgency of implementing eradications when a new species is detected, the consultation process should be time-constrained not to excessively delay the decision-making process. For this aim, public involvement in the decision process for the creation of biosecurity agencies with the power to eradicate alien species, or in the definition of national/international strategies to reduce threats posed by biological invasions, can result more effective in respect to efforts aimed to build up consensus over single eradication projects.

Methodologies

Areas

All ecological communities are invasible (Williamson 1996). Nevertheless, areas most likely to be invaded, areas where the effects of invasions might be more severe and areas where the feasibility of eradication is generally highest can be identified in order to evaluate priorities for intervention.

Introduction points

In view of the need of a rapid response to new invasions, early warning and control efforts should be concentrated in areas where new introductions are most likely to occur. Individuals that are accidentally imported or have escaped from captivity are more likely to be found in areas around harbours, airports, breeding farms, game parks and zoological gardens. Often pet species that have escaped or been released from captivity first become established in urban and suburban areas.

Vulnerable environments

Recent invaders are most often found in disturbed sites (disturbance generally being considered a human-induced alteration of the ecosystem). This general pattern has been explained by a higher resistance to invasions by pristine ecosystems than by altered communities; however, it could also be explained by the higher probability of a species being transported into disturbed areas because of human activities (Williamson 1996).

Islands are particularly vulnerable to the effects of invasions because they contain the highest percentage of the world's endemic species of mammals and birds (Ceballos and Brown 1995, King 1995) and are often characterised by a simple ecosystem structure (Lodge 1993). This leads to a higher risk of total extinction than in invasions occurring on the mainland.

Corridors

Identification of potential corridors of invasive species and the concentration of removal efforts in these areas can reduce the risks of the spread of IAS and/or of their immigration from areas where they are already established. When the containment of a species is a priority, the identification of potential corridors and the realisation of local eradication in the corridors can be an effective strategy. In the case of the grey squirrel, the Italian national strategy is also based on the identification of key corridors of expansion, where to concentrate control efforts in order to halt or delay the species' colonisation of the Alps and the Apennines (Genovesi and Bertolino *in press* b).

Surface

The feasibility of eradications often depends on the size of the infested area, since larger areas require greater efforts. For example, rat eradications are considered eminently feasible on islands with areas up to 2000 ha (Veitch 1997) (see Box 4 for examples of campaigns carried out by the INRA), while 14 out of 16 goat eradications carried out in New Zealand before 1990 were realised on islands of 350 ha or less (Parkes 1990).

Geographically isolated areas

For a combination of the above-mentioned parameters, islands (and ecological islands such as lakes, etc.) generally represent ideal areas in which to perform eradications; in fact, islands are highly vulnerable, can have limited surface area and their re-colonisation is less likely than on the mainland.

Time of the year

Optimisation of the effects on target species

In order to increase the efficiency of control methods, the period of intervention should be defined on the basis of the biology of the IAS and of other time related ecological parameters of the area. Capture success may be related to the season: in the case of the grey squirrel, trapping success is highest in spring, when the availability of seeds is low and the animals are more attracted by baits. Similarly, the eradication of rabbits from three island of the Kerguelen archipelago by means of poisoned baits was realised in winter, when food availability is scarce and baits are more attractive (Pascal 1999).

Annual population variations can also strongly affect the feasibility of eradications. The success of the coypu eradication in the UK has been partly ascribed to the low population levels determined by cold winters, which occurred just before and during the eradication campaign (Gosling 1989)

Minimisation of undesired effects

A careful definition of the best period in which to carry out an eradication program can minimise the undesired effects on non-target species or on the environment. In the eradication of rabbits from three islands in the Kerguelen archipelago, the decision to carry out the campaign in winter was also taken because Skuas, potentially vulnerable to indirect intoxication, are not present on the islands in this season (Pascal 1999). Pascal (1999) suggests that the eradication of rats from islands should preferably be performed outside the nesting period of birds inhabiting the islands.

Accessibility

The timing of the eradication campaign should also be decided on the basis of greatest accessibility, which can be a major problem in cold climates or in relation to seasonal variations of sea conditions when campaigns are carried out on islands. For example, Pascal (1999) carried out rat eradications from islands in the September-October period also because climatic conditions permitted accessibility.

Choosing removal methods

Methods to control or eradicate terrestrial vertebrates can be classified as mechanical (trapping or shooting), chemical (rodenticides), sterilisation, and biological (Orueta and Ramos 1998):

- Mechanical methods, including trapping, shooting and hand removal, have been widely used for the eradication of terrestrial vertebrates other than rats;
- Chemicals are very effective in the eradication of rats and other rodents, and have been applied also to carnivores, birds, goats and pigs; the use of poisons is prohibited under the Bern Convention;
- Sterilisation has not been effective in natural populations, but can be used in small urban populations when public acceptance limits the use of other techniques. Immuno-contraception is a promising technique for the future but is still in an experimental phase.
- Biological control: in some cases, highly specific pathogens have greatly reduced target populations (e.g. Myxomatosis and Rabbit Haemorrhagic Disease to control rabbits); the release of natural vertebrate enemies for controlling rabbits and rodents has generally been counterproductive (e.g. hogs, *Mustela* and *Herpestes* spp., cats, foxes often became pests themselves).

When the methodologies of an eradication are chosen, the efficiency, selectivity and undesired effects of the available techniques should be considered.

Efficiency

The most appropriate methods should be used to increase the probability of achieving the goal. The rate of removal should exceed the rate of increase of the population. A combination of methods can be effective in ensuring adequate efficiency at both high and low densities.

Selectivity

Selectivity of the removal methods for the target species can affect their efficiency and, more importantly, the effects on non-target species: if critical, selectivity can be tested by small-scale experimental applications of the methods.

Undesired effects

Effects on non-target species, especially rare or endangered species, should be carefully evaluated. While a limited number of accidental deaths of non-target species are often unavoidable, these undesired effect can be minimised by carefully defining the devices, baits and time of the year of the eradication. For example, live trapping and hand removal can be more selective than other techniques.

Apart from limited selectivity, the disturbance caused by the control efforts and the risks to the operators should also be considered and minimised. When poisons are used, the availability of antidotes should be ensured.

Lastly, eradication campaigns can also indirectly cause undesired effects on other components of the ecosystem, for example if the target species limits other IAS by predation or competition (Feare 1999).

Public acceptability

Public acceptability can be a major problem in eradications of pets – especially domestic cats - and other popular species (e.g.: the grey squirrel, see Box 3). When appropriate, methods of removal should be defined after a consultation process allowing involvement of the public.

Trial eradication

A trial eradication (e.g. grey squirrel: box 3, or Genovesi and Amori 1999; coypu: Gosling and Baker 1997) is often used to gather crucial information (removal success, removal selectivity, equal vulnerability within the population, etc.) in order to better estimate the required time and effort.

Monitoring

Adaptive approach

Prediction of the results of eradication efforts, and of the effects on the population and other components of the biota, is generally difficult. Therefore, it is important to adopt an adaptive approach, constantly monitoring the effects of the removal and correcting the operative planning when necessary.

Success of eradication

It can be difficult to verify the success of an eradication (Usher 1989) and it is thus important to concentrate adequate resources to assess weather it has been successful or not. Indeed, a correct evaluation of the results of an eradication is fundamental, since even a few reproductive individuals left in the wild can lead, in the medium term, to the failure of the entire campaign. Hence an evaluation of the achievement of the objectives should always be included in an eradication program.

To determine if an eradication has been successful, methods capable of detecting a species even at very low densities are needed. An absolute measure of population size is not necessarily required; indexes of abundance can be sufficient, provided 1) they are sensitive to changes close to zero and 2) they intercept the origin when plotted against true density (Bomford and O'Brien 1995).

In order to minimise overlap between implementation and evaluation tasks, an independent body should be mandated to evaluate the results of the eradication campaign. In the case of the coypu eradication from the UK, laboratory staff carried out an independent survey throughout the region for the last four years of the campaign (Baker 1999). In the goat eradication carried out on Capra, the success was evaluated by a team led by the leader of an earlier expedition, who had doubted that eradication was possible (Parker 1995).

Evaluation of results in relation to desired outcomes

Achievement of the target objectives and observance of the time-table should be thoroughly evaluated.

Undesired effects

A constant monitoring of the undesired effects, especially if threatened species are present in the area, should be included in the planning. Indirect effects of the campaign on other components of the ecosystem should also be considered in the monitoring. Methods should be revised if undesired effects are identified.

Data bank of eradication projects

The effective and timely collection and sharing of relevant information and experiences of eradication campaigns is an essential element to promote advances in research and better management of IAS. Priority should thus be given to the creation of easily accessible data banks containing information about IAS, the methods to control them, and previous successful eradication campaigns. Dissemination of information about unsuccessful projects are also needed, and should be guaranteed.

Recovery

When possible, the recovery of native ecosystems after a successful eradication should be included in the planning. For example, the re-introduction of native species locally driven to extinction by the IAS should be considered, if possible and as appropriate. Eradication should never be seen as the ultimate goal, but as one step in a process of ecosystem restoration and biodiversity preservation.

CONCLUSIONS AND RECOMMENDATIONS

Guidelines for eradications of terrestrial vertebrates

- Considerable technical experiences has been gathered in the last century on the control of invasive alien vertebrate species. Today eradication is a powerful conservation tool, able to significantly reduce biodiversity loss and to mitigate negative impacts of invasions. Nevertheless, eradications are a complex and costly management option, and should not be abused.
- Priority for eradication campaigns should be given to 1) newly formed propagules, especially when non-reversible effects are predicted, 2) species representing a major threat to biodiversity, 3) species already established in the wild, causing reversible effects on native ecosystems, 4) species for which eradication is most feasible. Impacts and reversibility of effects can be evaluated through a risk assessment procedure. The development of lists of

priority, also based on “black lists” of species known to be harmful to biodiversity, can help speed up the decision process.

- Desired outcomes should be clearly defined. In small-scale projects (e.g. newly formed propagules), based on the precautionary approach, the aim is the prevention of possible future impacts. In large-scale campaigns (e.g. ruddy duck, grey squirrel) the desired outcomes should be described in detail.
- Eradications should be planned primarily in the most vulnerable ecosystems and where such campaigns are most likely to be successful. Therefore, islands should be considered priority areas for eradications.
- An eradication should not be attempted unless it is ecologically feasible and has the necessary public support and financial and political commitment. The feasibility of eradication should be scientifically assessed on the basis of the most relevant biological characteristics of the target species, the ecological relationships of the species with the invaded area, the socio-economic aspects, the political commitment, the legal framework, the public support, and the availability of funds. A trial eradication can be a useful tool to collect the information needed to assess an eradication’s feasibility. The feasibility study should defined the chances of success of the eradication in the best possible way. Worst case scenarios should be adopted.
- When controversies are expected, decisions should be made after a consultation process. In this case, adequate information must be provided to the public, the decision process should adequately consider the resulting comments, and decision makers should be open to new ideas and inputs. Since rapid action is critical, the consultation process should be time-constrained in order not to excessively delay the decision-making process.
- International co-operation is fundamental when eradication of transboundary populations are planned or when the prevention of re-invasions requires international regulations.
- A clear decision line should be ensured. The best option is to define national agencies to be entrusted with all the necessary decisions and actions. In this regard, the creation of national biosecurity agencies may be a useful step in the implementation of effective management policies.
- Eradication methods should be selected primarily on the basis of their efficiency, since it is essential that all individuals of the population be vulnerable to the removal methods.
- Removal techniques and the timing of the operation must be chosen in order to minimise undesired effects. Monitoring of undesired effects should be included in the planning, and eradication methods should be revised if significant impacts on non-target species are recorded.
- Monitoring the success of the eradication is crucial. Methods capable of detecting species at very low densities are needed. An adaptive approach, based on a constant revision of the results obtained, is the best option.
- Monitoring of the desired outcomes is also important. Effects of the removal on the native species and ecosystems should be carefully evaluated and circulated.
- Recovery of native ecosystems after the eradication should be included in the planning when possible and as appropriate.
- Methods to prevent re-invasions, and contingency plans to rapidly remove new propagules if prevention fails, should be defined when possible and as appropriate.
- Effective and timely collection and sharing of relevant information and experiences of eradication should be ensured, in order to improve management techniques.
- Information and awareness are fundamental aspects not only for eradications but more generally to address the problems of IAS; publicity campaigns on the issue should be a

priority of conservation. Eradication projects should include information to the public about the impact of the invasive alien species, the outcomes of the campaign, and the efforts to recover the native ecosystems.

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BOX 1: The Global Invasive Species Programme

The Global Invasive Species Programme (GISP) was created in 1997 to provide information to implement Article 8(h) of the Convention on Biological Diversity. This Article calls on Parties to "Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species". GISP is operated by a consortium of the Scientific Committee on Problems of the Environment (SCOPE), CABInternational (CABI), the World Conservation Union (IUCN), and the United Nations Environment Programme (UNEP). GISP is a component of DIVERSITAS, a programme on biodiversity science. With funding from a number of sources, GISP seeks to improve the scientific basis for decision making on invasives; develop capacities to employ early warning and rapid assessment and response systems (including the further development of a Global Invasive Species Database, and the co-ordination of a database network); enhance the ability to manage invasives; reduce the economic impact of invasives and control methods; develop better risk assessment methods; and strengthen international agreements.

GISP is developing new approaches to public education about invasives, improving understanding of the ecology of invasives, examining legal and institutional frameworks for controlling invasives, developing new codes of conduct for the movement of species, and developing new tools to quantify the impact of invasives. Its work involves dozens of scientists from all parts of the world.
(from GISP 2000)

BOX 2: Threat from the Ruddy Duck in Europe

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The North American ruddy duck *Oxyura jamaicensis* was introduced into the UK from North America in the 1940's. After escaping from captivity, ruddy ducks first bred in the wild in 1960 and increased to about 4,000 birds in 1998. Without control, North American ruddy ducks are expected to colonise continental Europe and threaten the native white-headed duck *Oxyura leucocephala* - a globally endangered species recorded as "Vulnerable" on the World List of Threatened Birds - with extinction through hybridisation and competition.

Between 1965 and 1996, there were over 900 records of some 1,500 ruddy ducks in 19 Western Palaearctic countries. Records are concentrated along the North Sea coasts of The Netherlands, Belgium, and Germany, in France and in southern Spain. Ruddy ducks now occur annually during the breeding season in nine Western Palaearctic countries and besides the UK annual breeding attempts probably take place in six: Belgium, France, Germany, Ireland, The Netherlands and Morocco (not Spain as most birds are shot). Large flocks of wintering birds have recently appeared in Spain and France. In January 1997, about 30 ruddy ducks were recorded in northern Spain following freezing conditions across northern Europe, and some 30-40 birds have wintered annually at Lac de Grand-Lieu in northern France since 1995/96. The number of ruddy duck records in the Western Palaearctic is still increasing, at a mean annual rate of 21% between 1976 and 1996. The greatest increase has been in The Netherlands where the number of records increased at 34% per year between 1984 and 1996.

The increase in continental records has been highly correlated with the increase in the UK ruddy duck population, even to the extent that the number of continental records has declined in years following declines in the UK ruddy duck population. It is unlikely that mass escapes from captivity could explain the recent appearance of large flocks of ruddy ducks in France and Spain. Therefore, most ruddy ducks occurring in mainland Europe probably originate from the introduced UK population, although additional birds undoubtedly escape from collections. DNA fingerprinting has ruled out the possibility that birds are natural transatlantic vagrants.

Since 1993, when the first international meeting was held to discuss the ruddy duck issue in the Western Palaearctic, there has been action in many countries. An appraisal of the level of implementation of country-by-country recommendations for ruddy duck control from the Council of Europe white-headed duck Action Plan reveals:

1) Monitoring of ruddy ducks in the wild is adequate in most countries;
2) The legal provision for ruddy duck control exists in all countries;
3) Many countries have, or are considering, a national ruddy duck strategy;
4) There is a commitment to eradication in three countries (France, Portugal, Spain) while the UK has conducted research into suitable control measures for ruddy ducks and has moved to a regional trial to assess the feasibility of nationwide eradication. This regional trial may reduce the UK population by over 1,000 birds. Spain, France and Portugal attempt to control all ruddy ducks and hybrids, with a total of 135 birds shot to date (68 ruddy ducks and 51 hybrids in Spain, 13 ruddy ducks in France, and one ruddy duck and two hybrids in Portugal). There is no ongoing control in six countries in which annual breeding attempts are thought to occur (Belgium, Germany, Iceland, Ireland, Morocco and The Netherlands);
5) Few countries have acted to address the potential threat posed by ruddy ducks escaping from captivity (although it was already illegal to keep ruddy ducks in Iceland and Norway and there are no birds in collections in Sweden). Few countries have mechanisms in place to monitor the numbers of birds kept in captivity and in four countries (Ireland, Italy, The Netherlands and Portugal) it is not illegal to release ruddy ducks into the wild. ruddy ducks can be traded freely in most countries;
6) Few countries have public relations strategies regarding ruddy ducks, although these are in place in those countries with ongoing control.

A strategic approach needs to be adopted if North American ruddy ducks are to be eradicated from the Western Palaearctic. An international eradication strategy needs to be produced, which is endorsed and implemented by all Western Palaearctic states. Individual countries need to produce national eradication strategies, in consultation with relevant interest groups. Both wild and captive birds should be eradicated, the former taking priority as these are thought to be the major source of birds reaching white-headed duck populations. The immediate priorities (1999-2002) for the control of wild ruddy ducks should be to assess the feasibility of eradication from the UK and to ensure that birds do not become established in other countries. With regard to captive populations, all countries should introduce and/or enforce legislation preventing the release and escape of ruddy ducks into the wild, and introduce schemes to monitor the numbers of birds kept in captivity. The ultimate goal should be to prohibit the keeping of ruddy ducks in captive collections.

The ruddy duck issue has demonstrated a reluctance to act on the Precautionary Principle with regard to controlling non-native species. A proactive, rather than reactive, approach to the ruddy duck problem would have saved much time, energy and money.

BOX 3: Eradication of the Grey Squirrel in Italy: Failure of the Programme and Future Scenarios

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The American grey squirrel (*Sciurus carolinensis*), introduced into Italy and the British Isles as a pet species, replaces the native red squirrel (*S. vulgaris*) through competitive exclusion, causes severe damage to forests and commercial tree plantations by bark-stripping, and is also suspected of being a source of *parapoxvirus*, which is lethal to the red squirrel. Italy has the only populations of grey squirrels living in continental Europe and an expansion of the species could cause an ecological catastrophe at a continental scale as previously experienced in the UK. The grey squirrel was introduced into Piedmont (North-West Italy) in 1948 and a population was rapidly established. For several decades, the grey squirrel was recorded only close to the release site, but after 1970 the species started to spread into the surrounding area.

From 1989, several international organisations and scientists, including the IUCN and the British Forestry Commission, informed the Italian authorities of the threat to the red squirrel posed by the grey squirrel, and urged the eradication of the species. The National Wildlife Institute (NWI, the Italian government agency for wildlife research and conservation) approved a recommendation to eradicate the grey squirrel from Italy, and warned the Ministry of Environment, the Ministry of Agriculture, and all local administrations (responsible for pest management plans) about the drastic expansion of the grey squirrel's range and on the risks related to its presence.

In 1996, the grey squirrel had greatly expanded its range, even colonising areas about 10 km from the continuous hilly woodlands of eastern Piedmont; the arrival of the species in the Alps and the hilly area was predicted in about 2 years. The total population size was estimated at 2,500-6,400 individuals by means of drey counts and capture-recapture censuses carried out in sample areas. In view of the urgency of removing the grey squirrel from Italy, in 1997 the NWI in co-operation with the University of Turin produced an action plan for eradication of the species. One of the first steps of the plan was the experimental removal of the small population present in the Racconigi Park, in order to test effective and humane techniques, while further steps of the eradication should have been carried out by the local authorities. The project was sent to all the main Italian non-governmental organisations (NGOs) and, on the basis of the resulting comments, the following protocol was adopted: 1) live-trapping of the squirrels, in order to avoid risks for non-target species; 2) frequent control of traps, to reduce captivity of animals; 3) anaesthesia with halothane, a tranquilliser that reduces stress in rodents; 4) subsequent euthanasia of animals with an overdose of halothane; an 5) constant supervision by a veterinarian. On the basis of the revised protocol, most NGOs approved the eradication plan.

In April 1997, the project was officially presented and the trial eradication started in May 1997. The preliminary results were very encouraging: during only 8 days of trapping at Racconigi, 188 animals (> 50% of the estimated population) were trapped and euthanased. The adopted procedure of euthanasia resulted in a significant reduction of stress to the squirrels: they reached unconsciousness in less than a minute and could be euthanased in the field, with very limited manipulation.

However, some radical animal rights groups strongly opposed the project, organising small demonstrations at a local level. Then, in June 1997, they took the NWI to court and managed to halt the project. The case was closed in July 2000, with the full acquittal of the NWI.

The three year legal struggle caused the failure of the entire campaign. The enforced early termination of the trial eradication did not allow an estimation of the effort needed to remove the total population and local administrations did not proceed with the planned eradication. As a result of the suspension of any actions, the species has significantly expanded its range and an eradication is no longer considered feasible. In fact, the range of the grey squirrel has reached the continuos wood belt of the Alps and the hilly system of eastern Piedmont. It has colonised residential areas where any operation would require the authorisation of private park owners. An expansion into the Alps is predicted to occur in the next few decades (Lurz *et al*. 1999) and a further expansion into a large portion of Eurasia is a probable scenario.

A strategy for the control of the grey squirrel was developed in May 2000 by the Ministry of Environment in co-operation with the NWI (Genovesi and Bertolino *in press* b). The aims of the strategy are to: 1) identify and protect key areas for the conservation of viable populations of the red squirrel and 2) contain the grey squirrel in order to delay its expansion to neighbouring countries and to the mountain system of Italy.

BOX 4: Eradication of alien micromammal species from island ecosystems

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Method: general scheme.
To prevent or minimise the destruction of non-targeted species, the overall operations were divided into two phases. During the first phase, the use of live traps placed on a quadrate (30m x 30m for *Rattus* spp.) allowed the release of all non-target species. Population size estimates were obtained through removal data and bait consumption. When the daily number of trapped rats reached zero, the second phase began. In this phase, the set of traps remained in place and plastic tubes (45 cm length, 9 cm diameter), each filled with 500 g of a toxic bait (toxic = generally chlorophacinone anticoagulant), were placed near the traps. The experiment was interrupted when the daily rate of disappearance of baits reached zero. All the systems were re-activated one year later, to improve the eradication result; then, permanent bait stations were put in place to prevent re-invasions.

General results.
All the trappable animals were captured during the first 11 days; they constituted 75-98% of the total population of the alien species, depending on the target species and the size of the islands. The total eradication of *Rattus norvegicus* from 10 islands belonging to 3 archipelagos off the coast of Brittany and of *R. rattus* from 4 islets off Martinique (French Caribbean) was achieved in 21 days of operations. The successive use of trapping and then poison permitted a 75-98% reduction of the input of poison into the food chain and thus a decrease by the same percentage of the secondary poisoning hazard.

Despite the precautionary approach, a limited number of accidental deaths of non-target species were recorded (passerine birds captured in the traps, rabbits ingesting poisonous baits). This undesired effect was limited and without long-term consequences for the non-targeted populations.

Consequences of the disappearance of the alien species were:
- a significant increase of the number of pairs of 3 species of terrestrial passerine birds,
- a significant increase of the reproductive success of 3 species of marine birds,
- the resettlement of one marine bird species,
- a very significant increase in the number of an indigenous shrew, and
- a numerical increase of a reptile species.

Région	Archipelago	Island	area (ha)	Targeted species	estimated population size	eradication year	Success
Britanny	**Sept Ile**	**Bono**	**25**	***R. norvegicus***	**700**	**1994**	**yes**
		île aux Moines	**10**	**-:-**	**200**	**-:-**	**-:-**
		île Plate	**5**	**-:-**	**100**	**-:-**	**-:-**
		île aux Rats	**0,2**	**-:-**	**20**	**-:-**	**-:-**
	Rimains	**Rimains**	**2**	**-:-**	**100**	**-:-**	**-:-**
		Chatellier	**1**	**-:-**	**50**	**-:-**	**-:-**
		Rocher de Cancale	**0,2**	**-:-**	**10**	**-:-**	**-:-**
	Molène	**Trielen**	**15**	**-:-**	**150**	**1996**	**-:-**
		Enez ar C'hrizienn	**0,6**	**-:-**	**30**	**-:-**	**-:-**
Corsica	**Lavezzi**	**Lavezzu**	**110**	***R. rattus***	**?**	**2000**	
Caribbean	**Martinique**	**Burgaux**	**0,5**	**-:-**	**50**	**1999**	**yes?**
		Percé	**0,5**	**-:-**	**50**	**-:-**	**yes?**
		Hardy	**6**	**-:-**	**200**	**-:-**	**yes?**
		Poirier	**5**	**-:-**	**200**	**-:-**	**no**
	Guadeloupe	**Fajou**	**120**	***R. rattus***	**?**	**2001**	
				M. musculus	**?**		
				H. javanicus	**?**		

Alien mammal species eradication's from islands undertaken or planned by the Wildlife and Biological Conservation Group from the INRA institution .
(Rennes Station - France)

(1993 - 2001).

BOX 5: Mink eradication projects in northern Europe

The American mink in Europe

The American mink (*Mustela vison*) has been imported into Europe since the 1920s for fur farming and for deliberate introduction into the wild. The species' present range covers a large portion of eastern and northern Europe (Kauhala 1996), represents a major threat for the endangered European mink (*Mustela lutreola*) and it also affects many bird populations, especially on islands (Nummi 1996).

Baltic Sea

The American mink has colonised almost the entire Finnish and Swedish archipelagos in the last few decades, severely affecting native bird communities (Andersson 1999, Nummi 1996). Several control programs have been planned in order to mitigate the impact of the alien species.
In Sweden, experimental eradications have been realised in several areas to test for efficiency and to monitor effects on bird reproductive success (Andersson 1999).
In a group of islands of the Archipelago National Park in south-western Finland, with a total area of 12 x 6 km, a mink eradication project was carried out with the aim of recovering local bird populations (Nummelin and Högmander 1998). Minks were hunted with a portable leaf-blower (normally used to collect fallen leaves) and trained dogs. After the dog identifies a mink hiding-place, the leaf-blower is used to force the animal out of the burrow (Nummelin and Högmander 1998). In the first year, 65 minks were taken, and an average of 5-7 animals in the following years. Since 1998, no minks have been trapped and the eradication is considered successful. Many bird populations have increased after the control program, including black guillemot, velvet scoter, tufted duck, mallard and black-headed gull. No response was recorded in populations of the common eider, greylag goose, common merganser and large gulls (Nummelin and Högmander 1998, Nummi 1999). The short distance from the mainland and other islands, as well as the winter freezing of the Baltic Sea, makes a mink re-colonisation possible. Therefore, permanent monitoring and control are critical (contact Petri Nummi: pjnummi@ladybird.helsinki.fi).
In Estonia, a mink eradication project was successfully realised on Hiiumaa Island (1000 km^2) with the aim of re-introducing the European mink on the island. The local population originated from animals escaped from a now-closed breeding farm. During the campaign, 52 minks were trapped using 10 leg-hold traps, and success of the eradication was monitored through collection of mink presence signs in the breeding season. Re-colonisation seems unlikely, since the island is 22 km far from mainland. The campaign was realised by a highly trained staff of 1-3 people per season, with the co-operation of local operators; total cost of the intervention was estimated in 70,000-100,000 Euros. Funds were provided by the UK government, the Darwinian Initiative for Biodiversity foundation, and the Tallinn Zoo. A similar campaign is now planned on the second largest island of Estonia (Saaremaa, 2,500 km^2) for the same purpose (contact Tiit Maran: t.maran@tallinnlv.ee).

Iceland

In Iceland the American mink has been established since 1937 and is now present throughout the country (Hersteisson 1999). In recent years, several studies have been conducted to assess the feasibility of a total eradication of the species from the country (Hersteisson 1999), but no final decisions have been taken as yet. If such a program is carried out, it will be the largest vertebrate eradication ever realised in Europe (contact Hersteisson: pher@hi.is).