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THE APPLICATION OF THE EUROPEAN STRATEGY ON INVASIVE ALIEN SPECIES: AN EXAMPLE WITH INTRODUCED SQUIRRELS

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ABSTRACT - We assessed the cases of squirrel species already introduced into Italy inside the framework proposed by the European strategy on invasive alien species. We collected information on 9 introductions that originated 8 populations: 3 of grey squirrels (*Sciurus carolinensis*), 2 of Finlayson's squirrels (*Callosciurus finlaysonii*), and 3 of Siberian chipmunks (*Eutamias sibiricus*). Food opportunism and high reproductive rate may explain the high success rate in establishing new populations, even with a low propagule pressure. A negative impact on the red squirrel (*Sciurus vulgaris*) and damage to forestry and manufactures have been recorded in the areas of introduction. Accordingly to the European strategy, Italy is called to build-up a rapid response system in order to avoid further releases of alien squirrels in the wild. Meanwhile these species must be considered as a priority for trade restriction. Considering the risks posed to biodiversity and human activities, Italy must adopt a precautionary principle, removing small nuclei of introduced species before they spread in large areas.

Key words: black list, risk assessment, alien species, *Callosciurus*, *Sciurus*

RIASSUNTO - ***Applicazione della strategia europea sulle specie non indigene: un esempio con gli scoiattoli introdotti.*** Come esempio di applicazione della strategia europea sulle specie invasive introdotte, abbiamo analizzato la situazione degli scoiattoli introdotti in Italia. Su 9 introduzioni registrate, in 8 casi si sono formate popolazioni naturalizzate: 3 di scoiattolo grigio (*Sciurus carolinensis*), 2 di scoiattolo di Finlayson (*Callosciurus finlaysonii*) e 3 di tamia siberiano (*Eutamias sibiricus*). L'alto successo delle introduzioni, anche a partire da pochi animali rilasciati, è probabilmente legato all'opportunismo alimentare delle specie considerate e al loro elevato tasso riproduttivo. Al momento, nelle aree di introduzione sono segnalati fenomeni di competizione con lo scoiattolo comune (*Sciurus vulgaris*) e danni alla vegetazione arborea e a manufatti. In accordo con la strategia europea, l'Italia deve implementare un sistema di risposta rapida per evitare future introduzioni di scoiattoli. Nel frattempo queste specie dovrebbero essere sottoposte a misure restrittive del commercio. Considerando i possibili rischi per la biodiversità e per alcune attività umane, l'Italia dovrebbe adottare un principio di precauzione, rimovendo vecchi e nuovi nuclei di specie introdotte prima che queste si espandano su ampie superfici.

Parole chiave: lista nera, analisi del rischio, species alloctone, *Callosciurus*, *Sciurus*

INTRODUCTION

Invasive alien species (IAS) represent a severe risk to biodiversity, they may cause huge economic losses and can affect human activities (Wilcove *et al*., 1998; Mack *et al.*, 2000; Pimentel, 2000). It is also predicted that biotic invasions will become the major engines of ecological modification 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 (Ruesink *et al*., 1995).

To cope with this threat, the Convention on Biological Diversity calls for a hierarchical approach based on prevention of new introductions, eradication of unwanted alien species, and population control (guiding principles adopted in 2002 with Decision VI/23). Considering the transnational dimension of the problem, a cooperation at international, regional, transboundary and local levels is essential. In order to apply such an approach at the Pan-European scale, the Bern convention, on behalf of the Council of Europe, developed a strategy on IAS (Genovesi and Shine, 2004; Genovesi, 2005) that promotes the development and implementation of coordinated measures and cooperative efforts throughout Europe, to prevent or minimise adverse impacts of IAS on Europe's biodiversity, as well as their consequences for the economy and human health and well-being. The actions recommended by the strategy include: building awareness and support, collecting and sharing information, strengthening national policy and legal frameworks, promoting regional cooperation and responsibility, favouring prevention through early detection and rapid response, mitigating the impacts, and restoring native biodiversity.

Considering that an imported species has the possibility to escape and adapt to a new habitat even if not imported for being released into the wild, the strategy proposes that all importations are assessed through a comprehensive screening system based on risk analysis. The screening could be conducted with a 3-list system that considers: species already identified as highly invasive in one or more European states or proven to be invasive in other regions (black list), species classified as low risk following a risk assessment or based on long-standing experience (white list), other species not included in the black or white list, or which is data-deficient, that should be subjected to risk analysis prior to a decision on authorisation (grey list).

An already established analysis of existing information and experience on alien species could help making a preliminary assessment and identify priority species and areas for action. In order to provide an experimental application of the guiding principles of the European strategy on IAS, in the present paper we assess the cases of squirrel species already introduced into Italy, with the aim of: (i) proposing management options for the species already established; (ii) using information on the species to produce recommendation regarding the possible future importation of other squirrel species; (iii) using

this exercise to produce suggestions useful to implement a national strategy on IAS.

METHODS

We searched through the literature to compile a list of squirrel species introduced into Italy. All the data and articles collected were reviewed for species of squirrel introduced, date of introduction, number of founders, success or failure of introduction, negative impact on native fauna, vegetation, or human activities. A further research regarded other introductions worldwide of those species introduced into Italy. Articles on squirrel introductions were searched using electronic databases, including Zoological Records, Web of Science, Cab Abstracts. Internet searches on the Worldwide Web was performed using different search engine. During the search, terms such as "squirrel", "*Sciurus*", "*Callosciurus*", were matched with "introduction", "non indigenous", "alien species". Additional information was acquired using reference tracing from the books and articles collected. Several experts were contacted directly and provided new information and additional bibliographic sources.

RESULTS

1. Introductions into Italy

We recorded information about 9 squirrel introductions: 4 regarding the grey squirrel (*Sciurus carolinensis*) a species originated from North America, 2 concerning the Finlayson's squirrel (*Callosciurus finlaysonii*) from Thailand, and 3 about the Siberian chipmunk (*Eutamias sibiricus*) from Asia (Tab. 1). Single chipmunks have been observed also in other areas (Piemonte, Liguria, Friuli-Venezia Giulia, Trentino-Alto Adige, Lazio regions; Amori, 2002) and indicate a risk of the establishment of new populations. In 7 out of 9 introduction attempts, a population originated from the released animals. Only in 1 case the introduction failed, probably due to predation by cats on the few introduced animals (Currado *et al.*, 1997). The fate of the animals introduced at Trecate (Piemonte region, Northwestern Italy) is not clear. Some animals were removed from a park where they were introduced for the first time, but the discovery in 1999 of a dead individual at

Table 1 - Introduction of squirrel species in Italy and population trend.

Species	Year	Area	Animals released	Population trend	Source
S. carolinensis	1948	Turin	4	Increased	Bertolino *et al.*, 2000
S. carolinensis	1966	Genoa Nervi	5	Increased	Bertolino *et al.*, 2000
S. carolinensis	1980s	Rome	few	Failed	Currado *et al.*, 1997
S. carolinensis	1994	Trecate	6	Probably increased	Bertolino *et al.*, 2000
C. finlaysonii	1981	Acqui Terme	4	Increased	Bertolino *et al.*, 2000
C. finlaysonii	1980s	Maratea	few	Increased	Aloise and Bertolino unpub.
E. sibiricus	1970	Belluno	70-100	Increased	Dal Farra *et al.*, 1996
E. sibiricus	1970s	Verona	few	Slight increase	Amori and Gippoliti, 1995
E. sibiricus	1980s	Rome	?	Slight increase	Amori and Gippoliti, 1995

Coarezza (VA) along the Ticino river, and the following detection of grey squirrels in other areas only few kilometres apart from Trecate, seem to indicate that not all animals were removed and that they are spreading from Trecate (Fornasari *et al.*, 2002). Squirrel populations established in Italy originated in 4 cases from the release of 4-6 animals (Tab. 1), and also in 2 more cases only a few animals were released. Data on the spread of the species are available for 2 populations: the grey squirrel in Piemonte (Bertolino and Genovesi, 2003) and the Finlayson's squirrel at Maratea (Aloise and Bertolino, 2005). Both populations show a range expansion that follows a sigmoid growth curve, with a lag phase and a successive exponential range increase (Fig. 1). The grey squirrel was recorded in 2000 in a range of about 900 Km^2 (Bertolino and Genovesi, 2003), while the variable squirrel occupied an area of 26 km^2 in 2004 (Aloise and Bertolino, 2005).

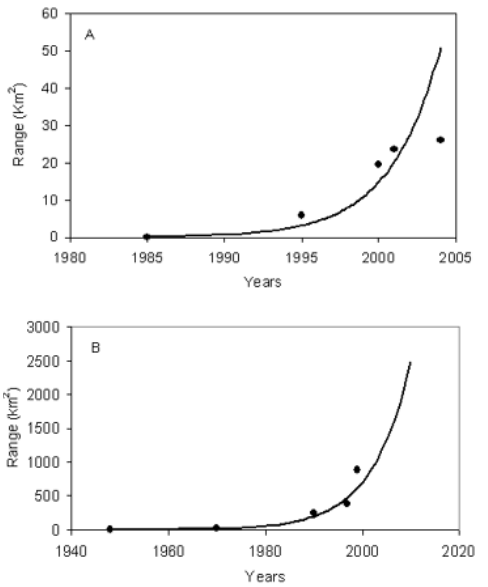

Figure 1 - Spread of the Finlayson's squirrel population at Maratea (A, from Aloise and Bertolino, 2005) and spread of the grey squirrel population in Piemonte region (B, from Bertolino and Genovesi, 2003).

2. Introduction in other countries

Grey squirrels were introduced into the United Kingdom and Ireland in the second half of the XIXth century and the first three decades of the XXth century (Laidler, 1980). Squirrels were released on 31 occasions in the British Isles and in 24 cases the population increased; in 11 cases, ≤ 10 animals were released (Tab. 2). In other 7 cases the introduction failed, the result was uncertain, or the increase was slighth (Laidler, 1980). In Ireland, a single release with 6 pairs of squirrels was successful and now the species is widespread (Teangana *et al.*, 2000). In the United States, 6 out of 9 introductions of the grey squirrel were successful (Zeiner *et al.*, 1990; Koprowski and Mawson, pers. com.), while in Canada 2 introductions (with 3 and 6-8 individuals, respectively) out of 4 were successful (Gonzales and Larsen, pers. com.). In South Africa 4 introductions originated populations that are slightly increasing, while in Australia 2 introductions failed to cause the establishment of a population (Lever, 1985).

The Siberian chipmunk has also been introduced into Austria, Belgium, France, Germany, the Netherlands and Switzerland (Riegel *et al.*, 2000; Long, 2003).

Table 2 - Introduction of *Sciurus carolinensis* in the United Kingdom (N = 31) and Ireland (N = 1) grouped by number of animals released and population trend (source: Laidler, 1980; Teangana *et al.*, 2000).

Animal released	Number of areas	Population		
		Increased	Slight increased	Failed / Uncertain
≤ 5	11	8		3
6-10	4	3	1	
11-100	6	5	1	
Not known	11	9	1	1

3. Impacts

The grey squirrel has negative impacts on the ecosystem and human activities (Tab. 3). In Great Britain, Ireland, and Italy the species is causing the progressive disappearance of the native red squirrel through a mechanism of competition (Gurnell and Pepper, 1993; Wauters *et al*., 1997; Gurnell *et al*., 2004). A role of a parapoxvirus in the replacement has also been suggested (Sainsbury *et al*., 2000). The grey squirrel represents a source of this pox-virus, that is lethal to the red squirrel (Duff *et al*., 1996; Sainsbury *et al*., 2000). In addition it has been highlighted the possibility that grey squirrels may have a negative impact on forest birds, especially on species nesting in cavities (Hewson and Fuller, 2003). In Great Britain the grey squirrel causes heavy damage to forests and tree commercial plantations because of bark-stripping (Rowe and Gill, 1985; Dagnall *et al*., 1998). Bark-stripping activity inflicts wounds that degrade severely timber quality and can facilitate the penetration of insects and fungi (Kenward, 1989; Dagnall *et al*., 1998). In Italy, damage to poplars, hornbeams and cereal crops has been recorded (Currado *et al*., 1987; Currado, 1993).The impact of the Finlayson's squirrel on the vegetation in the two areas of introduction is considerable. At Acqui Terme (Northwestern Italy), squirrels were observed to spend one third of their feeding time eating bark and sap (Bertolino *et al*., 2004). Considering only the 10 most palatable tree-species over 80% of the trees was damaged by squirrels, and on 42 trees (17.5% of the total), the stripped area was >500 cm^2 (Bertolino *et al*., in press). A similar impact on vegetation has been recorded in Maratea (Southern Italy), where in some areas all trees of *Ceratonia siliqua*, *Quercus virgiliana*, *Q. ilex*, *Olea europea*, were attacked by squirrels (Aloise and Bertolino, 2005).
The Siberian chipmunk is considered a pest species in some areas of its native range for the heavy damage to grain crops (Long, 2003), but no damage has been reported in Europe so far, although a possible impact to ground nesting birds has been suggested (Riegel *et al*., 2000).

4. Reactivity of authorities

Grey squirrels were introduced at Stupinigi (province of Turin, Piemonte

Table 3 - Introduced squirrels which have a negative interaction with native fauna and vegetation.

Introduced species	Threats/damage (Source)
Threats to native fauna	
Sciurus carolinensis	Competition with *Sciurus vulgaris* (Wauters *et al.*, 1997; Wauters *et al.*, 2000)
	Impact on forest birds? (Hewson and Fuller 2003)
Eutamias sibiricus	Negative impact to breeding birds? (Riegel *et al*., 2000)
Damage to vegetation	
Sciurus carolinensis	Bark-stripping in plantations, urban parks and natural forests. Damage to cereal crops (Currado *et al.*, 1987; Dagnall *et al.*, 1997)
Callosciurus finlaysonii	Bark-stripping in urban parks (Bertolino *et al.*, 2004; Aloise pers. com.)
Other impacts	
Sciurus carolinensis	Vector of disease (Parapoxvirus) (Duff *et al.*, 1996; Sainsbury *et al.*, 2000)
Sciurus carolinensis	Damage to electric cable (Authors, pers. observ.)
Callosciurus finlaysonii	Damage to electric cable and other manufacture (Authors, pers. observ.)

region) in 1948 (Currado *et al*., 1987). The first reports on the conservation risks related to the presence of the grey squirrel in Piemonte were published in the 1980s (Tab. 4). The first eradication proposal was in 1987 and an action plan was prepared in 1997. The trial eradication was stopped by a recourse to the court from animal right groups and no other action was undertaken. This species, localized in an area of 25 km^2 during the 1970s, reached 380 km^2 in 1987 and about 900 km^2 in 2000 (Bertolino and Genovesi, 2003).

Finlayson's squirrels were introduced at Acqui Terme (province of Alessandria) in 1981 (Bertolino *et al*., 1999), but the presence of animals in the area was reported to local authorities only in 1998. Similarly, the species was introduced at Maratea (province of Potenza) in the 80s, while the presence of the animals was reported to the National Wildlife Institute only in 2002. In both cases the report to the authorities was associated to the presence of damage produced by animals.

DISCUSSION

In the last 50 years, 9 introductions of 3 alien squirrels have been recorded in Italy. Only one introduction failed, while in the other cases few animals released led to established populations. Currently the grey squirrel is the most

harmful species because of its negative impact on the native red squirrel. In recent years the mechanism of competition between the two species has been partially explained (Wauters *et al*., 2001; Gurnell *et al*., 2004 and references therein), and the risk connected to the expansion of the grey squirrel highlighted (Lurz *et al*., 2001; Bertolino and Genovesi, 2003). Both the grey squirrel and the Finlayson's squirrel have a strong impact on forestry and tree plantations. We do not know how heavy will be the grey squirrel's impact on natural forests when it will reach the Italian Alps, but some tree species that are common in the alpine forests (e.g. *Fagus sylvatica*, *Acer pseudoplatanus*) are strongly debarked by the grey squirrel in England (Dagnall *et al*., 1998). Considering the level of damage produced by the Finlayson's squirrel at Acqui Terme and Maratea, it is likely that this species could have a strong impact when it will reach the hilly system in Piemonte and the Apennines in Basilicata (Southern Italy).

Presently there are no data about impacts due to the Siberian chipmunk populations introduced into different European countries. Some suggestions of a possible negative impact on ground nesting birds are still not proved (Riegel *et al*., 2000). However, this species is established in many European countries, in some cases with large populations (Bertolino *et al*., 2000; Riegel *et al*., 2000), and the frequent observation of animals in the wild suggests the risk of the establishment of new populations.

Established populations of introduced squirrels often originated from the release of few individuals. Propagule pressure is one of the characteristics that is reported to be a limit in the establishment of many species (Kolar and Lodge, 2001). Squirrels that have been introduced into Italy have many ecological characteristics that cause a predisposition to be good invaders; this may explain the high success rate in establishing new populations, even with a low propagule pressure. They are food opportunists, with a high reproductive rate: sexual maturity is reached early, females have a short gestation period and usually have more than one litter per year, with a mean litter size of more than one (Gurnell, 1987; Tamura *et al*. 1988). Furthermore, they are often sold as pets and frequently set free in gardens; thus the [in]voluntary rate of introduction is probably high.

Considering that species imported may escape or may be released, reducing the introduction of new invasive alien species relies on good knowledge of what species must be prevented from entering a country. The identification of a range of taxonomic groups with a high invasive potential could help in the screening processes necessary to set up black lists of prohibited species. Since squirrels are invasive in many places where they have been introduced, they must be considered as priority species for trade restriction.

The spread of the grey squirrel and the Finlayson's squirrel showed an exponential range increase that is consistent with the pattern predicted by Elton (1927) for the establishment of a species. It is described by a sigmoid growth curve, characterised by a first phase of settlement, when the possibili-

Table 4 - Timetable of the grey squirrel invasion in Italy: main conservation, legal and management steps, and range expansion data.

Year	Milestone	Range (km^2)	References
1948	Introduction of two pairs of grey squirrels at Stupinigi	<0.1	Currado *et al.*, 1987
1970	Last red squirrel observed at Stupinigi	25	Wauters *et al.*, 1997
1980	First report of the species in a regional publication		Baratti, 1980
1981	First report of the species in a national scientific publication		Cagnolaro, 1981
1987	First proposal of eradication		Currado *et al.*, 1987
1990		243	Wauters *et al.*, 1997
1997	First article on the replacement of the red squirrel by the grey one in Italy		Wauters *et al.*, 1997
1997		380	Bertolino and Genovesi, 2003
1997	Action plan for the eradication of the species		
1999		880	Bertolino and Genovesi, 2003
2000	Strategy for the conservation of the red squirrel in Italy		Genovesi and Bertolino, 2001

ty of extinction is high, a phase of rapid increase, and finally a stabilisation phase. The presence of a lag phase, when the species remain localized, that seems to be characteristics of many introductions (Williamson, 1996), can limit the possibility to build-up a rapid respond system. Usually, local authorities are reluctant to consider the possibility to remove introduced animals until severe damage is recorded. During the lag phase the population remains at a low density and in this phase threats to ecosystems or human activities are often not yet obvious. Thus, in this phase, when the complete removal of the animals is a practicable option, it is difficult to get local support to the action. When the species start to spread faster, like the grey squirrel in Piemonte and maybe the Finlayson's squirrel at Maratea, the damage becomes obvious, but the possibility to eradicate the species decrease (Genovesi, 2004). Therefore rapid response is a critical element for effective prevention. The cases of squirrel introductions into Italy clearly show the limited ability to respond timely to new incursions and highlight the need of improving the capacity of the responsible authority in this regard. For this aim, it is critical to address technical, social and legal constraints, moving from the present reactive approach, to a proactive policy on invasive alien species.

Accordingly to the European strategy, Italy is called to build-up a rapid response system in order to avoid further releases of squirrels in the wild. Competent authorities should eradicate small populations of already established species and control grey squirrel

populations in order to contain further expansion, concentrating control in corridors toward other countries. Considering the risks posed to biodiversity and human activities, Italy must adopt a precautionary principle, removing small nuclei of introduced species before they spread in large areas. In a more general contest "every alien species needs to be managed as if it is potentially invasive, until convincing evidence indicates that it does not present such a threat" (McNeely *et al*., 2001).

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