

# Restricted access to private properties limits management of invasive alien species: A literature review and case studies

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## ABSTRACT

Biological invasions are one of the major drivers of global environmental change and there is a need to develop integrated strategies to counteract this phenomenon. Eradication is an effective management option to mitigate the deleterious impacts of invasive alien species (IAS). Eradication can be achieved if all reproductive individuals are removed and population recovery is prevented. However, individuals may survive removal operations in private areas if interventions are not allowed. Here, we present 1) three case studies in which restricted private property access prevented the local eradication of invasive alien populations, and 2) a list of reasons for denying access to private properties and a list of actions implemented or suggested by managers to facilitate access and reported in 29 reviewed papers. The restricted access affected the local eradication of three Eastern grey squirrel (*Sciurus carolinensis*) populations in Italy. In Lombardy region, in one area a planned eradication did not start and in another area the implemented eradication failed due to the refusal from the owner of a large private property to grant access to managers. In Umbria region, the lack of collaboration from an Italian financial institution produced a delay of 15 months in the removal. In our case studies, therefore, a single person or institution denied access for a personal gain or presumed internal security. The reasons behind landowner opposition may be diverse and individual attitudes towards IAS management will depend on interactions with owners. According to our review, in many cases the denial of access takes place in a general perception of mistrust or opposition to the project as the results of a limited engagement of local people. Such opposition often jeopardizes control activities, with profound negative consequences on eradication, especially at landscape scale. Bottom-up approaches aiming at involving stakeholders can increase the possibility to achieve IAS eradication, however appropriate legislation remains pivotal to enforce eradication in case of non-cooperative behaviour.

## 1. Introduction

Biological invasions are one of the major drivers of human-induced global environmental changes, which are negatively impacting biodiversity, ecosystem services and human well-being (Simberloff et al., 2013; Shackleton et al., 2019). Since the magnitude of biological invasions continues to increase (Seebens et al., 2017), there is the need to develop strategies to improve our capacity to counteract this phenomenon (Simberloff et al., 2013).

Eradication is nowadays considered as one of the most effective management options to counteract the deleterious impacts caused by invasive alien species (hereafter IAS). Successful eradications have led to substantial results in terms of species conservation and ecosystems restoration (Jones et al., 2016; Robertson et al., 2017). The removal of populations of IAS makes a significant contribution to the global conservation goals required by the Convention on Biological Diversity (CBD, 1992), such as the Aichi Biodiversity Target 9 (i.e., invasive alien species and pathways are identified and prioritized, priority species are

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controlled or eradicated) and Target 12 (i.e., threatened species extinctions are prevented). In accordance with these targets, the EU Biodiversity Strategy for 2030 requires to manage established IAS so to decrease the number of Red List species they threaten by 50 % (<http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0380&from=EN>).

Eradication is particularly effective within the framework of an early warning and rapid response system, which can allow to quickly remove small propagules and avoid the establishment or spread of invasive species (Booy et al., 2020; Robertson et al., 2020). The strengthening of early warning systems and the implementation of a rapid response capacity are critical elements for integrated pest management and for the effective containment and control of epidemic animal diseases. However, eradication may be a valid management option also at later invasion stages, since a number of populations that established across large spatial scales have been successfully eradicated (Jones et al., 2016; Robertson et al., 2017). Although many successful eradications took place on islands, mainland populations that occur in isolated habitats surrounded by a non-permeable matrix share many characteristics with insular populations, and can therefore be eradicated in a similar fashion (Adriaens et al., 2015).

Eradication is “the complete and permanent removal of all wild populations from a defined area by a time-limited campaign” (Bomford & O'Brien, 1995). Assessing the feasibility of an eradication campaign requires the evaluation of several biological and technical parameters, as well as social and political factors which can affect the success of any management countermeasure (Bomford and O'Brien, 1995; Crowley et al., 2017). Here, we focus on some criteria considered fundamental to achieve eradication (Bomford & O'Brien, 1995): the rate of individuals' removal must exceed the increase rate of the target population at any density; immigration should be prevented; and all reproductive or potentially reproductive individuals should be exposed to removal. The first criterion is associated with the removal effort, and thus to human power, motivation and funds available. Removal rate usually declines at low population densities and for a reduction of the population size to zero is necessary to maintain a high removal effort, even for a long time (Gosling and Baker, 1989). The second criterion, i.e. immigration prevention, can be achieved for areas delimited by effective barriers, whether they are real physical barriers or margins maintained by control to prevent recolonization, or with isolated populations. The last criterion requires that all reproductive and potentially reproductive individuals must be removed to avoid a population recovery. The three criteria are interconnected, since individuals that are not at risk of removal could continue to reproduce and spread into previously targeted areas where all individuals were eliminated, thus increasing the population density.

Fundamental criteria to achieve eradication might not be satisfied when invasive species colonize private areas in which the unavailability of the owners constrains the access to managers. This may be more common in urbanized areas. Land or private property owners could deny access to their properties, thus directly or indirectly contrasting the removal of invasive individuals and jeopardizing control activities. Indeed, Bomford & O'Brien (1995) identified not only the criteria essential for achieving IAS eradication, but also some other ‘desirable criteria’ which determine if eradication is a priority over other management approaches. They also recognized that the socio-political environment plays a role in determining the prospects for successful eradication. Key socio-political criteria include the avoidance or reduction of conflicts with local communities, the existence of clear administrative goals, and the removal of legal barriers; this last criterion includes securing access to private land for managers to ensure that all invasive individuals are removed.

Many eradication projects received strong opposition from NGOs and other sectors of the society concerned for animal welfare and the use of lethal measures (e.g. Bertolino and Genovesi, 2003; Crowley et al., 2017, 2019). Although several papers have already proposed strategies to

avoid, mitigate or resolve conflicts with different sectors of the society (e.g. Perry and Perry, 2008; Crowley et al., 2017, 2019), how the access of private properties can jeopardize alien species management has been overlooked.

We present three Italian case studies in which restricted private property access prevented the local eradication of invasive Eastern grey squirrel (*Sciurus carolinensis*, hereafter grey squirrel) populations (in Lombardy region) and significantly delayed the effective removal of another invasive population of the same species (in Umbria region). We also review the literature to find other cases where non-cooperative interactions with owners of land and private properties hampered eradication projects and to explore which actions have been implemented, or suggested, to address this issue.

## 2. Grey squirrel case studies

The grey squirrel is an American species replacing the native Eurasian red squirrel (*Sciurus vulgaris*, hereafter red squirrel) in Great Britain, Ireland and Italy, where the alien species has been introduced for ornamental purposes or as escaped pets (Bertolino, 2008). The replacement is mainly due to exploitation competition for food resources, with the introduced species more efficient in their use (Wauters et al., 2002a, b). In Great Britain, where grey squirrels carry a squirrelpox virus which is lethal for the native species, the replacement is much faster (Tompkins et al., 2002). This virus is not present in grey squirrels in Italy (Romeo et al., 2018) where, however, spillover of a common parasitic helminth of grey squirrels to naïve red squirrels occurs (Romeo et al., 2018; Santicchia et al., 2020).

The grey squirrel was introduced in Italy multiple times from 1948 onwards (Martinoli et al., 2010; Loy et al., 2019); also, alien grey squirrels were translocated from one area to another within the country (Signorile et al., 2016). The primary introduction and secondary translocation of animals generally occurred for ornamental purposes, with animals released in private properties, urban green areas or nearby (Martinoli et al., 2010). In urban parks and private properties, grey squirrels reach high densities also due to supplementary feeding provided by citizens, thus becoming easily visible and highly appreciated by owners and visitors (Merrick et al., 2016). Grey squirrel populations in urban and suburban parks may function as sources of propagules for the colonization of surrounding landscapes, depending upon the characteristics of the environment and the distance to suitable woodlands.

Modelling simulations have shown that the grey squirrel can potentially spread across most of Europe (Bertolino et al., 2008; Di Febbraro et al., 2016, 2019). Therefore, introduced populations have been actively managed for eradication or spatial control when too widespread (Bertolino et al., 2015). In Italy, squirrels are generally removed through live-trapping and euthanasia; only for a small population in Genoa Nervi (Liguria) and for part of the population in Umbria, live-trapped animals were surgically sterilized and released in an urban park (Scapin et al., 2019).

The current invasive range of the species in Italy encompasses open territories, protected areas, small and large cities, public green areas and many private properties. Therefore, the management of populations requires the collaboration of many institutions (e.g., local wildlife and park services, regional authorities, mayors of municipalities) and the involvement of citizens. Particularly, in the presence of large private properties within the range of a target population, it is essential to involve the owners to get access. Therefore, the management plans have foreseen to identify and contact landowners; however, their collaboration is not always granted. Decision on whether to adhere or not could be based on a plethora of elements. First of all, landowners can refuse to collaborate because they are against killing the squirrels. Social conflicts in IAS management have been described for multiple taxa and they are generally related to the lethal techniques adopted (Bertolino and Genovesi, 2003; Estévez et al., 2015). In particular, humaneness seems to be the most important factor regarding the decision to support or oppose

squirrel control activities, and methods which do not involve any direct killing are the most acceptable (Dunn et al., 2018). The grey squirrel is indeed perceived as an appealing mammal, and divergence of views on the need to euthanize animals easily arise (Bertolino and Genovesi, 2003; Benson, 2013). For these reasons, the citizen's attitude towards grey squirrels and the removal activities has been considered a critical element to inform grey squirrel management in Italy (La Morgia et al., 2017).

## 2.1. Lombardy

In Lombardy region (Italy), the grey squirrel invasive range is fragmented in numerous nuclei distributed across seven large areas. Control activities started in three areas within the European EC-SQUARE LIFE project and continued after the end of the project. Aim of this LIFE project was to develop methods to eradicate or control grey squirrel populations in different socio-ecological contexts.

### 2.1.1. Case 1

One of the areas, called Adda, was composed by 6 subunits, two in close proximity with only red squirrels and the other four at increasing distances and colonised by grey squirrels (Fig. 1). In subunits 3–5, nearly the whole territory was accessible to managers. After two years of trapping, grey squirrels were extirpated from these sub-units in 2014, and native red squirrels from neighbouring populations consequently recolonized subunit 5 (Fig. 1).

Successful removal of the grey squirrel in subunit 6 was interrupted by one private estate owner who refuse to grant access to a large park (Table 1, 6 ha, 2.3 % of the subunit) inhabited by an important sub-population of grey squirrels. This estate was used as a revenue for matrimonies, company feasts, and other receptions and grey squirrels represented an extra attraction for the park. In collaboration with the authorities of the regional park managing the surrounding landscape, we had several phone calls and email exchange, instrumental in explaining the importance of removing the local squirrels for the entire regional control project. Additionally, we repeatedly proposed to arrange meetings in order to reach a management compromise. Despite these efforts, the owner never accepted to meet project staff, not even

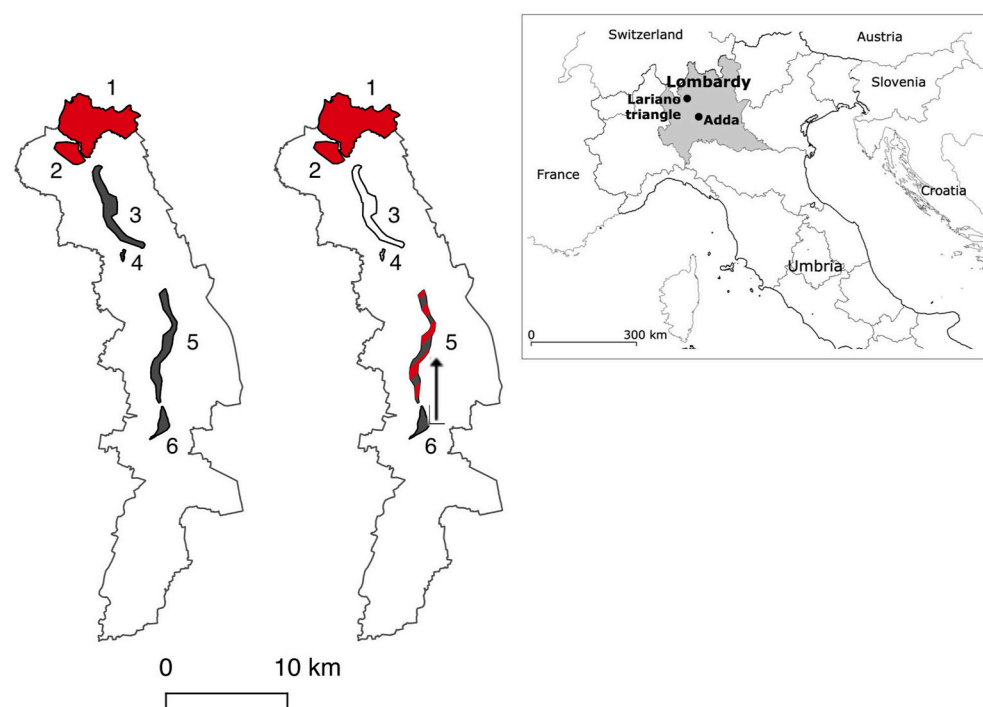
**Table 1**

Area covered and available for trapping and removal efforts for the case studies in Perugia (Umbria) and along Adda (Lombardy).

| Region                              | Lombardy  |              | Umbria                     |              |           |              |
|-------------------------------------|-----------|--------------|----------------------------|--------------|-----------|--------------|
| Area                                | Adda      |              | Perugia                    |              |           |              |
| Management Unit                     | Subunit 6 |              | MU 28 & neighbouring units |              | MU 65     |              |
|                                     |           |              |                            |              |           |              |
| <i>Difficulties</i>                 |           |              |                            |              |           |              |
| Access to the main private property | No        |              | Yes                        |              | No        |              |
|                                     |           |              |                            |              |           |              |
| <i>Surface areas</i>                | ha        | % total area | km <sup>2</sup>            | % total area | km2       | % total area |
| Total area                          | 35.02     |              | 6.2                        |              | 2.2       |              |
| Area of the main private property   | 6.51      | 18.59        | 0.4                        | 6.45         | 0.06      | 2.73         |
| Accessible private properties       | 0         | 0.00         | 0.8                        | 12.90        | 0.13      | 5.91         |
| Total accessible area               | 26.45     | 75.53        | 3.4                        | 54.84        | 0.36      | 16.36        |
|                                     |           |              |                            |              |           |              |
| <i>Trapping activity</i>            |           |              |                            |              |           |              |
| Period/Dates                        | 2011–2017 |              | 2016–2018                  |              | 2016–2018 |              |
| Trap-days                           | 1380      |              | 6315                       |              | 2726      |              |
| Trap-days/km2                       | 394       |              | 1019                       |              | 1239      |              |
| Squirrels removed                   | 82        |              | 567                        |              | 184       |              |
| Squirrels removed/trap-days         | 0.06      |              | 0.09                       |              | 0.07      |              |

when the town administration proposed to act as facilitator. Repeated contacts with the other owners highlighted that many of them would be willing to allow entry if the animals were first removed from the largest property, which, hosting numerous squirrels, acted as a source of dispersing animals.

To avoid the spread of grey squirrels toward other areas, a periodical trapping activity was implemented in public places around the private properties in subunit 6. Between 2014 and 2017, grey squirrels from this subunit dispersed along the river corridors into subunit 5, colonizing also the woodland that hosted the largest local red squirrel population (see also Santicchia et al., 2020). In subunit 5 and 6, 170 animals have



**Fig. 1.** Adda management area in Lombardy. On the left, the subunit 3–6 (in dark grey) where grey squirrels were present at the beginning of the activities (left); on the right, subunits (3–5) where grey squirrels were removed. Areas in red indicate red squirrel presence. After grey squirrel removal, subunit 5 was first recolonized by red squirrels and then by grey squirrels in dispersion from subunit 6. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

been removed from 2014 onwards (82 in susunit 6, Table 1). Hence, in this case, the lack of collaboration from the owner of a key property has prevented the complete eradication of the grey squirrel from a large area and transformed the intervention into an expensive ongoing control program.

### 2.1.2. Case 2

In the Lariano triangle (Fig. 1), an incipient small and localised population of grey squirrels was concentrated in and around a vast estate of an international foundation. Contacts with the administrators were held by email and phone and the eradication project was presented and explained. The administrators asked extra evidence to back up the conservation importance of grey squirrel control, and we obtained two letters of support to our project by two of the most eminent American academic researchers working on grey squirrels in their native range. Despite these letters strongly advocated that our project was crucial for the conservation of native red squirrels, the foundation declined access to the estate for carrying out grey squirrel trapping because of a presumed violation of the security and privacy of their international hosts. This refusal had cascading effects on neighbouring smaller private landowners. Since at least 60 % of the local population occurred in the land owned by the foundation, the neighbouring landowners no longer recognized the purpose of admitting us to work on their properties and decided not to collaborate. The eradication of this small nucleus of grey squirrels was therefore considered not possible.

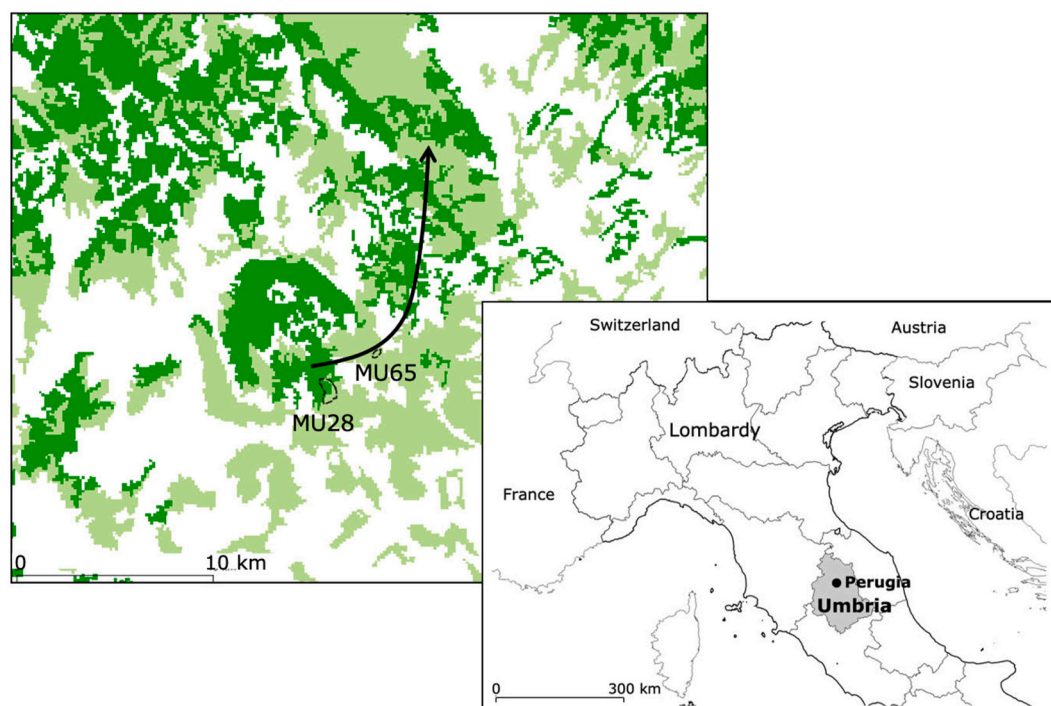
### 2.2. Umbria

In Umbria Region, in 2015 the grey squirrel was present with one population distributed over an area of 36.9 km<sup>2</sup> in the city of Perugia and neighbouring areas. Management actions have been implemented in the framework of the European LIFE U-SAVEDS project, aimed at eradicating grey squirrels from this area, and are still ongoing. Management units (MU) were identified by considering anthropogenic and

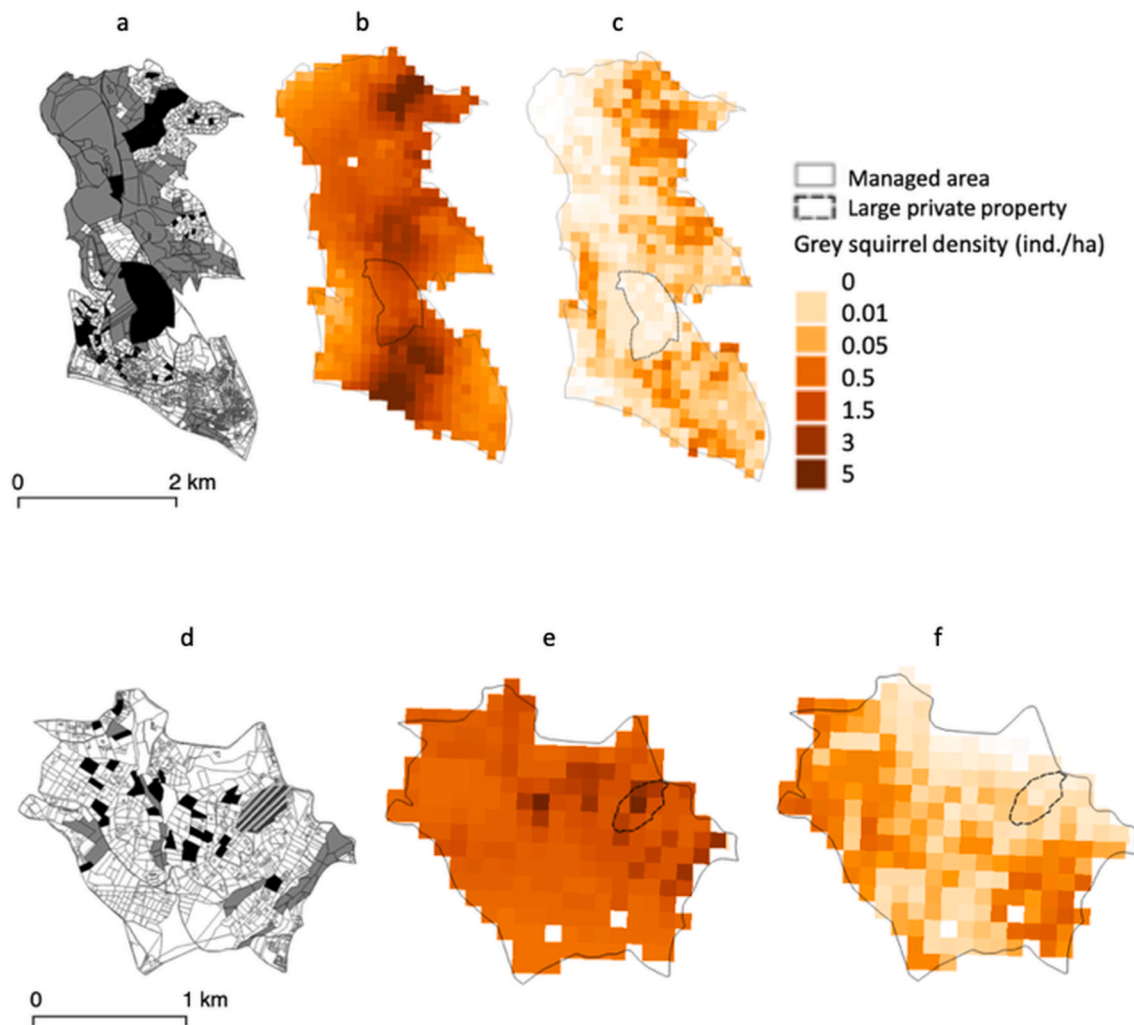
natural features of the area, and general knowledge about the local distribution of the species (Fig. 2). Two large and fenced properties were identified as critical areas for the success of the eradication plan. These properties were both characterized by a strategic geographic position across the invaded area and habitats highly suitable for the grey squirrel.

The first key property was in MU28 (Table 1), in the core area of the grey squirrel invasive range. The landowner granted access to this property in January 2016 and the grey squirrels' removal started immediately after. To avoid recolonization, captures were also implemented in the neighbouring MUs and the accessible area summed up to 55 % of the total spatial extent of the MUs (Fig. 3a). 366 and 201 squirrels were removed, respectively in 2016 and 2017 (Fig. 4). As a consequence of the control activities, the local densities of grey squirrels seemed substantially reduced, as revealed by the results of density surface models (DSMs, Hedley & Buckland, 2004; Miller et al., 2013) fitted to direct observations of the animals gathered in 2015 (Fig. 3b) and 2017 (Fig. 3c) through a point transect distance sampling approach (Buckland et al., 2001). At the end of the project, in October 2018, no grey squirrels were detected in MU28.

The second key property was located further to the north-east, within MU65 (Table 1). Removal of the grey squirrel from this area was considered relevant for the overall success of the project because the MU is close to a north-eastern ecological corridor potentially connecting the Perugia city area to the Apennines (Fig. 2). The managers of the large property were contacted following the directions of a communication plan focusing on targeted communication and a meeting was organized. However, at the end they refused any collaboration. The area is owned by an Italian financial institution and the reason for the refusal to cooperate was ascribed to security issues. After the denial of this major landowner, a very low proportion of smaller landowners accepted to collaborate with the project activities and the total accessible area for grey squirrel control was very limited (16 %, Table 1, Fig. 3d). Capture activities were substantially delayed for 15 months (Fig. 4) and when they started, traps were placed at the boundaries of some private



**Fig. 2.** Location of the Umbria Region and the city of Perugia in Italy, and map showing the distribution of woodlands in the managed areas and surroundings (dark green: broad-lived and mixed forests; light green: other woodlands). The map also shows the location of the two large and fenced properties identified as critical areas for the success of the eradication plan in the MU28 and MU65. The black arrow suggests the direction for the potential expansion of the grey squirrel via a north-eastern ecological corridor connecting the Perugia city area to the Apennines. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)



**Fig. 3.** Accessible areas and spatial distribution of grey squirrel densities in the Perugia area. Panels a, b and c refer to the areas surrounding the first large property (in MU28) and they show: the private accessible particles (in black), the free access areas (grey) and inaccessible areas (white) (a); the spatial distribution of grey squirrel density, as resulting from the density surface models fitted to distance sampling data gathered in 2015 (b) and in 2017 (c), i.e., before and after control activities. The same maps (d, e and f) are shown for the areas surrounding the second large property in MU65 (black area dashed in grey in panel d).

properties, mainly along public roads. This strategy required a considerable increase in the time devoted to fieldwork to place and constantly check the traps during the day. The results achieved from 2015 to 2017 in terms of reduction of the grey squirrel densities are shown in Fig. 3e and f.

Because of the difficulties encountered, the eradication of the grey squirrel from the Perugia area could not be achieved within the time frame of the LIFE Project (2014–2018), creating problems to find additional resources for the following years. Nevertheless, the densities of the alien species estimated through conventional distance sampling were significantly reduced, from 3.37 ind./ha (coefficient of variation,  $CV = 0.18$ ) in 2015, to 0.38 ind./ha ( $CV = 0.21$ ) in 2017. The removal campaign is still ongoing and recent monitoring revealed the presence of the native red squirrel in new areas, including the first key private property.

### 3. Literature review

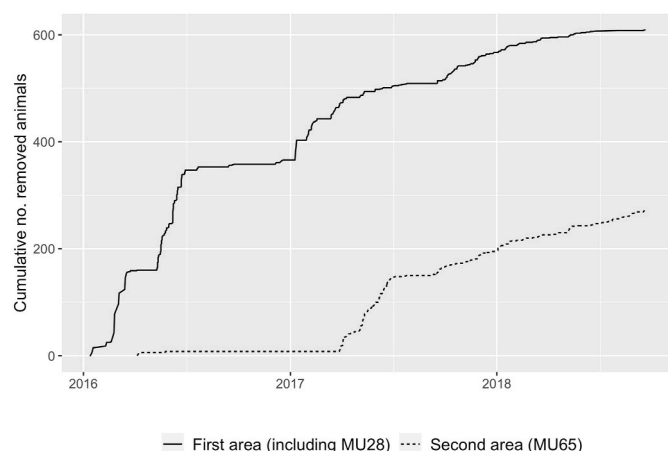
We conducted an extensive literature review in April 2021 to exemplify cases in which restricted access to private properties hampered management of invasive species. We searched for studies in Google Scholar by using the following keywords: access restriction, accessibility, alien species, control, eradication, invasive species,

restricted access, management, private properties. Additional references were retrieved by tracking the bibliography of selected articles.

We retrieved 29 papers: 26 reporting difficulties in controlling or eradicating IAS because of restricted access to private properties and three that explicitly declared the support of citizens and the possibility to act in private lands (Supplementary Material 1). In one of these three cases, residents even self-taxed themselves to pay a private trapper to remove iguanas (Engeman et al., 2018). It is probable that many other successful projects were supported by private owners, without this being specifically reported in the literature.

The papers retrieved deal with projects on mammals (12 papers), birds (2), reptiles (3), amphibians (6), insects (3), and plants (4). From these articles, we extracted sentences (edited for synthesis) that referred to the difficulty of accessing private properties and the indication of actions taken by managers to gain access (Supplementary Material 1). These texts were then elaborated in a list of reasons for denying entry to private lands as emerged from the literature and actions that have been undertaken or suggested as useful to overcome this opposition and facilitate access (Table 2).

Restricted access to private properties severely reduced the efficacy of the eradication campaign directed against, for example, the invasive American bullfrog (*Lithobates catesbeianus*) in France (Piria et al., 2017) and the guttural toad (*Sclerophrys gutturalis*) in South Africa (Vimercati



**Fig. 4.** Cumulative number of grey squirrels removed in the two areas of the Umbria case study. For the first area, the cumulative number includes the animals removed from both the accessible large property (MU28) and the surrounding areas. For the second area (including MU65), in 2016, a very low number of individuals was removed thanks to the collaboration of only a few landowners (see text for details). Starting from 2017, the removal strategy changed, and animals were removed at the boundaries of the inaccessible private properties.

et al., 2017; Davies et al., 2020). Even for the Asian tiger mosquito (*Aedes albopictus*), control has been occasionally hampered by access restriction. Although Unlu and Farajollahi (2012) reported high public support to control mosquitoes in Trenton (New Jersey, USA), several residents rejected any mosquito surveillance and control measures on their property as in Monmouth County (New Jersey, USA) (Fonseca et al., 2013). A very similar difficulty arose in Malaga (Spain), where management of the Asian tiger mosquito was limited by its spread across private houses that were not accessible to managers (Dana et al., 2019). Removing plants from private properties can also be problematic. Among 30 eradication projects covering 23 potentially invasive plant species with limited distributions on four Galapagos Islands, only four projects were successful, and all occurred inside the property of a single owner (Gardener et al., 2010). Among the remaining 26 projects on the contrary, six failed because landowners denied permission to carry on eradication in their properties (Gardener et al., 2010).

In many projects, citizens were not informed, not engaged, or not supportive (Table 2). People denying entrance to their lands did so more often in a general atmosphere of distrust or opposition to the project. These cases were often the results of a limited engagement of local people. When opposition raises, it is often too late to reverse the established belief. Therefore, a proactive approach is recommended, possibly involving the local community from the first phases of planning and decision. Engaging local people could result in a rise of the project and, in some cases, also in the participation of volunteers in the management of the target species (Sarat et al., 2015; Halliwell et al., 2019). Community engagement should, however, be sustained and effective and not only a proposed goal. An outreach campaign alone does not ensure the actual involvement of citizens, and confrontation meetings with main stakeholders are necessary (Varnham et al., 2011; Engeman et al., 2018). Inclusive models of engagement require collaborations between experts and laypeople to evaluate various management options (Crowley et al., 2017), and this must be based on mutual credibility. For instance, on Great Barrier island (New Zealand), part of the local community was concerned by aerial application of toxins used to eradicate rats, and it required at least five years to establish “a more informed and sympathetic societal framework” (Ogden and Gilbert, 2009).

Human relations with animals could be complex and emotional. For instance, ornamental pets are often selected because they convey positive emotions to buyers. Therefore, when alien populations are

**Table 2**

Reasons reported in the literature for denying access to private land properties as retrieved from the review of 29 articles, and actions implemented or suggested by scientists, managers or policy makers to facilitate access.

| Reasons for denying access to private lands                   | Actions to facilitate access                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Citizens are not informed or engaged                          | <ul style="list-style-type: none"> <li>Educate stakeholders about biological invasions</li> <li>Public meeting, mailings, and door-to-door visits</li> <li>Many small meetings are probably better than larger public meetings</li> <li>Outreach with all available means, e.g. TV, radio, social media, newspaper and magazine articles, talks and presentations, website, newsletters</li> <li>Establish agreements with owners about land management to improve relations between managers and them</li> </ul> |
| Disagreement about species impacts                            | <ul style="list-style-type: none"> <li>Provide information during meeting and through media</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                            |
| People are skeptical about eradication's success              | <ul style="list-style-type: none"> <li>Explain why eradication is needed and how it will be achieved</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                   |
| People distrust local authorities                             | <ul style="list-style-type: none"> <li>Involve the local community through a bottom-up approach</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                        |
| Citizens are not supportive                                   | <ul style="list-style-type: none"> <li>Engagement of local people to raise the profile of the project</li> <li>Involving local volunteers in the project</li> <li>Show the return of native species after alien removal</li> <li>Adapt eradication protocols</li> <li>Adopt humane methods of killing</li> <li>Animals sterilized instead of being euthanized</li> <li>Explore the perception of landowners and stakeholders through interviews or other approaches.</li> </ul>                                   |
| The alien species is considered a resource                    | <ul style="list-style-type: none"> <li>Provide alternative socio-economic benefits</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Citizens do not see any link with the local economy           | <ul style="list-style-type: none"> <li>Provide more comprehensive socio-economic benefits (e.g. through green tourism for charismatic native species)</li> </ul>                                                                                                                                                                                                                                                                                                                                                  |
| Emotional and complex human relationships with the IAS exist  | <ul style="list-style-type: none"> <li>Provide information during meetings and through other means</li> <li>Act rapidly before habituation to the species becomes widespread</li> </ul>                                                                                                                                                                                                                                                                                                                           |
| <b>Restricted access to private lands</b>                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Some owners deny to grant access to private lands             | <ul style="list-style-type: none"> <li>Get permission from relevant landowners and involve the community</li> <li>Adopt legislation that provides staff powers of access to private lands for IAS control</li> </ul>                                                                                                                                                                                                                                                                                              |
| Areas are restricted for hunting                              | <ul style="list-style-type: none"> <li>Get permission from relevant landowners and involve the community</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                               |
| Areas are restricted for a disease outbreak                   | <ul style="list-style-type: none"> <li>Work in other areas and wait</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Plants are not effectively controlled/regulated by landowners | <ul style="list-style-type: none"> <li>Authorities should support the efforts of those private landowners who do not regulate the plants</li> </ul>                                                                                                                                                                                                                                                                                                                                                               |

established in urban areas, they can easily become an attraction for people. In the Netherlands, the support of citizens was considered crucial for the success of the red-bellied tree squirrel (*Callosciurus erythraeus*) eradication campaign, as many squirrels lived in private gardens (La Haye, 2019). The collaboration of the local community was gained by spaying trapped squirrels and maintaining them in captivity rather than causing their death. When residents could not accept the use of toxic bait in rats and mice eradication, live trapping was used as a supplementary technique (Engeman et al., 2018). Adapting eradication protocols is, therefore, a possibility to engage and find a middle-ground with local communities. However, such adaptation is not always possible since the behaviour of neophobic or trap-shy rodents could make live-trapping ineffective, or sterilization (Scapin et al., 2019) and

maintenance of large number of animals in captivity could be problematic due to cost, infrastructure needed, and animal welfare. Croft et al. (2021) concluded that fertility control alone is unlikely to achieve rapid enough population reduction to prove a viable cost-effective alternative to completely replace culling of grey squirrels. Therefore, the adaptation of protocols to answer requests from the community should always focus on the management goal. On the contrary, Kalnicky et al. (2014) found that citizens accepted coqui frogs (*Eleutherodactylus coqui*) when they were more common on their property; therefore, managers may be more effective at engaging citizens in control efforts before habituation becomes widespread.

When the local community is engaged, providing evidence of results could help involving reluctant landowners. On Anglesey island (UK), the grey squirrel eradication led to the re-establishment of native red squirrels, thus persuading many sceptics on the need to remove alien species. The re-establishment of the charismatic red squirrel also provided significant socio-economic benefits to green tourism (Schuchert et al., 2014; Halliwell et al., 2019). Conversely, in New Zealand, the eradications of goat (*Capra hircus*) and Himalayan tahr (*Hemitragus jemlahicus*) populations failed because landowners restricted hunting access to their land being concerned about losing a valued food resource (goats, Parkes, 1990) or the availability of trophy males for fee-paying clients (tahrs, Forsyth and Tustin, 2001).

The lack of legislation that provides staff powers of access to private lands for IAS control has been proposed as a negative point in some projects (Dana et al., 2019; La Haye, 2019; Davies et al., 2020). Such legislation was adopted in Great Britain and South Africa, but it has not been applied yet in both countries (Crowley et al., 2017; Davies et al., 2020) and therefore its effectiveness is still unknown.

#### 4. Discussion

An eradication is successful when all individuals of the target population are removed (Bomford & O'Brien, 1995). Accordingly, all areas where animals are present should be accessible to managers. For species widespread over large ranges and that will inevitably be present in many private properties, this entails the need to contact many owners for gaining the permission to access their properties; therefore, gaining access has been recognized as one of the greatest challenges for many management programs. Dana et al. (2019) also suggested that the permission to work on private properties should be included in the feasibility analysis of IAS management actions. Indeed, lack of access to part of the area occupied by an invasive population may imply that not all reproductive and potentially reproductive animals are exposed to removal, an aspect which is obviously fundamental to achieve eradication (Bomford & O'Brien, 1995).

Here, we presented three case studies regarding the attempted eradication of invasive grey squirrels, which failed or were delayed because of the refusal from the owners of large key properties to grant access to managers.

In Lombardy, the lack of collaboration from the owner of a large property – who was interested in having the squirrels as an attraction for those attending matrimonies, company feasts, and other receptions – prevented the eradication of the grey squirrel population from a management subunit, while the species was successfully removed from other three adjacent subunits. In these subunits, management actions resulted in the recolonization of the forested habitats from native red squirrels which had gone extinct due to the competition with their invasive congener. Nevertheless, a complete eradication was not achieved and, despite ongoing control activities, the grey squirrel is currently re-invading the areas from which it was extirpated. In another management unit, the refusal to collaborate by an international foundation led to consider the eradication of a small grey squirrel population as impractical.

In Umbria, two large and fenced properties were identified as critical areas for the success of the eradication plan. In the first area (MU28),

grey squirrels were initially widespread and abundant. However, the main property and other landowners collaborated, so that grey squirrels were fully extirpated. In the second area (MU65), the landowner of the main property and many other landowners did not collaborate. Here, the lack of collaboration postponed the start of the removal activities and increased trapping effort and overall cost having to remove invasive squirrels at the boundaries of the inaccessible private properties, which significantly increased the time devoted to fieldwork. Overall, in Umbria the removal activities resulted in a significant reduction of the density of the alien species, while the native red squirrel colonised new areas. Nonetheless, the delay of a year and a half in the start of the management actions did not allow to reach the eradication within the four years of the European LIFE project and new financial resources now need to be sought.

A review of the literature suggested the existence of analogous cases where eradication projects failed due to the lack of collaboration from private owners. Even the support for the control of the Asian tiger mosquito, which poses a high human health risk, is known to vary widely across different areas, with some residents refusing any kind of inspection (Fonseca et al., 2013; Dana et al., 2019).

Indeed, private decisions can have profound consequences for eradication at the landscape scale (Costello et al., 2017). Social factors play an overriding role in determining the success of eradications or other management options (Bremner and Park, 2007; Crowley et al., 2017). While a number of projects received strong support from local inhabitants (Saunders et al., 2007; Engeman et al., 2018), conflicts raised in the community can frustrate management attempts. Negative attitudes can arise from mutualistic wildlife value orientations (Manfredo et al., 2009), which are common in urbanized areas, where negative emotions connected with wildlife management could be amplified (Jacobs et al., 2014; Liroy et al., 2019). In this context, also species charisma may influence media portrayal and public perceptions, promoting opposition to management (Jarić et al., 2020).

Management projects not supported by the whole community can more easily cause owners to refuse to collaborate. In our case studies, indeed, we noticed that the behaviour of owners seemed to be influenced by the attitude of the neighbours, with individual decisions partly depending on interactions across owners, as in a network game (Jackson and Zenou, 2014; Costello et al., 2017).

The whole social and ecological context should be addressed to engage landowners in invasive species management. Indeed, besides ethical issues, there may be other reasons for landowners to decide whether or not to adhere to the proposed management plans. In some cases, the owners simply do not want people inside their properties, while the decision to be involved may also depend on the level of contribution by other citizens and the likelihood of the plans being effective and maintaining an ecological balance (Niemiec et al., 2017). Informing and involving community stakeholders is important in creating socially acceptable eradication operations, which facilitate interactions with landowners and cooperative behaviours. Landowners may be willing to share responsibility with the central governments for the eradication of invasive alien species, depending on their perspectives. The latter are in turn associated with ecological and social features of the landscape, and with conservation perceptions and policy preferences that can be affected by communication and information networks (Siebert et al., 2006; Urgenson et al., 2013).

Bottom-up approaches aiming at the involvement of community stakeholders have thus been considered as a potential solution for the management of invasive species. In this respect, door-to-door campaigns and direct contact with owners could facilitate cooperative interactions (Baldacchino et al., 2017). Such actions certainly require time and resources, but they have proven valid at engaging citizens, and they can certainly be most effective in the early stages of invasion, before habituation or even affection to the alien species becomes widespread (Kalnicky et al., 2014). Examples of successful engagement include the control of invasive pines in a coastal zone of southern Brazil (de Sá

Dechoum et al., 2018), of coqui frogs (*Eleutherodactylus coqui*) introduced to Hawaii (Beard et al., 2009), and the cooperation among multiple agencies, a private resort and local citizens to eradicate Polynesian rats (*Rattus exulans*) on Cocos Island, Guam (Engeman et al., 2018).

However, there are cases where involvement may fail or be incomplete. Landowners may be motivated to control invasive species, but they may not be fully aware of their role in spreading species to other areas (Fenichel et al., 2013). This problem is related to a mismatch of scales at which the different processes occur. Biological invasions take place at the landscape scale, with movement of animals (or spread, for plants) that may occur among multiple private properties. On the contrary, individual owners are generally incentivised to consider the costs and benefits of controlling species in their own property only, rather than considering the damage at landscape level, thus generating ‘externalities’ (Fenichel et al., 2013; Epanchin-Niell and Wilen, 2014). Owners may also differ in their experience and perception of the issue, for instance because damage or control costs vary between different properties. Additionally, owners might not be informed on the issue or might disregard the consequences of their actions on adjacent owners, thus adopting a non-cooperative behaviour that compromises management (Costello et al., 2017).

Despite efforts to involve community stakeholders and citizens, there may be cases where owners refuse to grant access to their lands for the most diverse reasons. In our case studies, the refusal came from a financial institution and an international foundation with armed surveillance, which did not want strangers on their properties, and from a private owner, who believed grey squirrels were a useful attraction for a business associated with social ceremonies, such as weddings and other parties. Since in these cases non-cooperative behaviours from a minority of people can jeopardize the results of the project, a top-down approach that enforces eradication to reluctant landowners may be identified as an alternative solution. For example, in Europe, the Regulation (EU) 1143/2014 on invasive alien species (the IAS Regulation) has introduced an obligation to manage the species included in a list of Invasive Alien Species of Union Concern. The EU Member States have transposed this IAS Regulation, and in different countries IAS operations may take place on private properties according to national laws. Interestingly, and in relation to our case studies, the Italian law (National Legislative Decree 230/2017) now provides that the competent authorities (i.e., the Majors) adopt the measures necessary to guarantee access to private areas in case the eradication of such IAS of Union Concern is requested. However, the Decree was not in force when grey squirrel eradications were attempted in Lombardy and Umbria. A similar legislation is in force in many European countries (e.g., Belgium, France, England, Scotland) and in South Africa (Davies et al., 2020). Having enforced a legislation is not a guarantee for a successful outcome. Legislative action creates tension, with enforcement counteracting the engagement that would be gained by a more collaborative approach. We therefore do not support a general application of this enforcement but consider the availability of a dedicated legislation as fundamental to address specific situations.

Squirrel eradications may be particularly difficult. The perceived impact can be low or even null, since the invasive squirrels can also be interpreted as ‘a good’ by some citizens and landowners, while they can be regarded as a nuisance (‘a bad’) by others. As a consequence, the access to private properties could be regarded as one aspect of a more complex issue related to communication and removal techniques that are employed (Piria et al., 2017). The involvement of citizens in the decision making process and as volunteers in management activities can increase the success of invasive species eradication, reduce their cost, and help raise awareness and build public support (Bryce et al., 2011; Ford-Thompson et al., 2012; de Sá Dechoum et al., 2019). Nonetheless, the existence and enforcement of the correct legislation is pivotal in case of failure of the bottom-up approach.

## CRredits

PG, SB, GV, VLM: Conceptualization, Methodology; SB, GV, VLM, AM, LW: Data curation; SB, GV, VLM: Writing, Original draft preparation; PG, SB, GV, VLM, DP, AM, LW: Writing- Reviewing and Editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2021.113318>.

## References

- Adriaens, T., Baert, K., Breyne, P., Casaer, J., Devisscher, S., Onkelinx, T., Pieters, S., Stuyck, J., 2015. Successful eradication of a suburban Pallas's squirrel *Callosciurus erythraeus* (Pallas 1779) (Rodentia, Sciuridae) population in Flanders (northern Belgium). *Biol. Invasions* 17, 2517–2526.
- Baldacchino, F., Bussola, F., Arnoldi, D., Marcantonio, M., Montarsi, F., Capelli, G., Rosà, R., Rizzoli, A., 2017. An integrated pest control strategy against the Asian tiger mosquito in northern Italy: a case study. *Pest Manag. Sci.* 73, 87–93.
- Beard, K.H., Price, E.A., Pitt, W.C., 2009. Biology and impacts of Pacific Island invasive species: 5. *Eleutherodactylus coqui*, the coqui frog (Anura: Leptodactylidae). *Pac. Sci.* 63, 297–316.
- Benson, E., 2013. The urbanization of the eastern gray squirrel in the United States. *J. Am. Hist.* 100, 691–710. <https://doi.org/10.1093/jahist/jat353>.
- Bertolino, S., 2008. Introduction of the American grey squirrel (*Sciurus carolinensis*) in Europe: a case study in biological invasion. *Curr. Sci.* 95, 903–906.
- Bertolino, S., Genovesi, P., 2003. Spread and attempted eradication of the grey squirrel (*Sciurus carolinensis*) in Italy, and consequences for the red squirrel (*Sciurus vulgaris*) in Eurasia. *Biol. Conserv.* 109, 351–358. [https://doi.org/10.1016/s0006-3207\(02\)00161-1](https://doi.org/10.1016/s0006-3207(02)00161-1).
- Bertolino, S., Lurz, P.W., Sanderson, R., Rushton, S.P., 2008. Predicting the spread of the American grey squirrel (*Sciurus carolinensis*) in Europe: a call for a co-ordinated European approach. *Biol. Conserv.* 141, 2564–2575.
- Bertolino, S., Martinoli, A., Paoloni, D., Marsan, A., Wauters, L., 2015. The grey squirrel in Italy: impacts and management. In: Shuttlesworth, C., Lurz, P.W.W., Hayward, M. (Eds.), *Red Squirrels: Ecology, Conservation & Management in Europe*. European Squirrel Initiative, Woodbridge, Suffolk UK, pp. 163–173.
- Bomford, M., O'Brien, P., 1995. Eradication or control for vertebrate pests? *Wildl. Soc. Bull.* 23, 249–255.
- Booy, O., Robertson, P.A., Moore, N., Ward, J., Roy, H.E., Adriaens, T., et al., 2020. Using structured eradication feasibility assessment to prioritize the management of new and emerging invasive alien species in Europe. *Global Change Biol.* 26, 6235–6250. <https://doi.org/10.1111/gcb.15280>.
- Bremner, A., Park, K., 2007. Public attitudes to the management of invasive non-native species in Scotland. *Biol. Conserv.* 139, 306–314.
- Bryce, R., Oliver, M.K., Davies, L., Gray, H., Urquhart, J., Lambin, X., 2011. Turning back the tide of American mink invasion at an unprecedented scale through community participation and adaptive management. *Emerg. Infect. Dis.* 144, 575–583.
- Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., 2001. *Introduction to Distance Sampling*. Oxford University Press, Oxford.
- CBD (Convention on Biological Diversity), 1992. The Convention on Biological Diversity. Secretariat of the CBD, U. N. Environment Programme, Montreal. Available from: <http://www.biodiv.org/convention/convention.shtml>.
- Costello, C., Quérou, N., Tomini, A., 2017. Private eradication of mobile public bads. *Eur. Econ. Rev.* 94, 23–44. <https://doi.org/10.1016/j.eurocorev.2017.02.005>.

- Croft, S., Aegerter, J.N., Beatham, S., Coats, J., Massei, G., 2021. A spatially explicit population model to compare management using culling and fertility control to reduce numbers of grey squirrels. *Ecol. Model.* 440, 109386. <https://doi.org/10.1016/j.ecolmodel.2020.109386>.
- Crowley, S.L., Hinchliffe, S., McDonald, R.A., 2017. Conflict in invasive species management. *Front. Ecol. Environ.* 15, 133–141.
- Crowley, S.L., Hinchliffe, S., McDonald, R.A., 2019. The parakeet protectors: understanding opposition to introduced species management. *J. Environ. Manag.* 229, 120–132.
- Dana, E.D., García-de-Lomas, J., Verloove, F., Vilà, M., 2019. Common deficiencies of actions for managing invasive alien species: a decision-support checklist. *NeoBiota* 48, 97–112.
- Davies, S.J., Bell, J.A., Impson, D., Mabin, C., Meyer, M., Rhoda, C., Stafford, L., Stephens, K., Tafeni, M., Turner, A.A., van Wilgen, N.J., Wilson, J.R.U., Wood, J., Measey, J., 2020. Coordinating invasive alien species management in a biodiversity hotspot: the CAPE Invasive Alien Animals Working Group. *Bothalia* 50 (1), a10. <https://doi.org/10.38201/btha.abc.v50.i1.10>.
- de Sá Dechoum, M., Giehl, E.L.H., Sühs, R.B., Silveira, T.C.L., Ziller, S.R., 2018. Citizen engagement in the management of non-native invasive pines: does it make a difference? *Biol. Invasions* 21, 175–188. <https://doi.org/10.1007/s10530-018-1814-0>.
- Di Febbraro, M., Martinoli, A., Russo, D., Preatoni, D., Bertolino, S., 2016. Modelling the effects of climate change on the risk of invasion by alien squirrels. *Hystrix* 27, 1–8.
- Di Febbraro, M., Menchetti, M., Russo, D., Ancillotto, L., Aloise, G., Roscioni, F., Preatoni, D.G., Loy, A., Martinoli, A., Bertolino, S., Mori, E., 2019. Integrating climate and land-use change scenarios in modelling the future spread of invasive squirrels in Italy. *Divers. Distrib.* 25, 644–659.
- Dunn, M., Marzano, M., Forster, J., Gill, R.M.A., 2018. Public attitudes towards “pest” management: Perceptions on squirrel management strategies in the UK. *Biol. Conserv.* 222, 52–63.
- Engeman, R.M., Avery, M.L., Shiels, A.B., Berentsen, A.R., VerCauteren, K.C., Sugihara, R.T., Duffiney, A.G., Clark, C.S., Eisemann, J.D., 2018. Diverse examples from managing invasive vertebrate species on inhabited islands of the United States. *Australas. J. Environ. Manag.* 25, 43–61. <https://doi.org/10.1080/14486563.2017.1393466>.
- Epanchin-Niell, R.S., Wilen, J.E., 2014. Individual and cooperative management of invasive species in human-mediated landscapes. *Am. J. Agric. Econ.* 97, 180–198. <https://doi.org/10.1093/ajae/aa058>.
- Estévez, R.A., Anderson, C.B., Pizarro, J.C., Burgman, M.A., 2015. Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. *Conserv. Biol.* 29, 19–30. <https://doi.org/10.1111/cobi.12359>.
- Fenichel, E.P., Richards, T.J., Shanafelt, D.W., 2013. The control of invasive species on private property with neighbor-to-neighbor spillovers. *Environ. Resour. Econ.* 59, 231–255.
- Fonseca, D.M., Unlu, I., Crepeau, T., Farajollahi, A., Healy, S.P., Bartlett-Healy, K., Strickman, S., Gaugler, R., Hamilton, G., Kline, D., Clark, G.G., 2013. Area-wide management of *Aedes albopictus*. Part 2: Gauging the efficacy of traditional integrated pest control measures against urban container mosquitoes. *Pest Manag. Sci.* 69, 1351–1361.
- Ford-Thompson, A.E.S., Snell, C., Saunders, G., White, P.C.L., 2012. Stakeholder participation in management of invasive vertebrates. *Conserv. Biol.* 26, 345–356.
- Forsyth, D.M., Tustin, K.G., 2001. Advances in New Zealand Mammalogy 1990–2000: himalayan tahr. *J. Roy. Soc. N. Z.* 31, 251–261.
- Gardner, M.R., Atkinson, R., Renteria, J.L., 2010. Eradications and people: lessons from the plant eradication program in Galapagos. *Restor. Ecol.* 18, 20–29.
- Gosling, L.M., Baker, S.J., 1989. The eradication of muskrats and coypus from Britain. *Biol. J. Linn. Soc.* 38, 39–51.
- Halliwell, L., Jenkins, R., Clews-Roberts, R., 2019. Grey squirrel management in the upland coniferous forest of Cloacog. In: Robinson, N., Shuttleworth, C. (Eds.), *Invasive Alien Species Colonisation Prevention: Your Guide to Early Detection and Rapid Response*. The Royal Society of Wildlife Trusts, pp. 91–100.
- Hedley, S.L., Buckland, S.T., 2004. Spatial models for line transect sampling. *JABES* 9, 181–199.
- Jackson, M.O., Zenou, Y., 2014. Games on networks. In: Young, Peyton, Zamir, Shmuel (Eds.), *Handbook of Game Theory*, vol. 4. Elsevier Science. <https://ssrn.com/abstract=2136179>.
- Jacobs, M.H., Vaske, J.J., Dubois, S., Fehres, P., 2014. More than fear: role of emotions in acceptability of lethal control of wolves. *Eur. J. Wildl. Res.* 60, 589–598.
- Jarić, I., Courchamp, F., Correia, R.A., Crowley, S.L., Essl, F., Fischer, A., González-Moreno, P., Kalinkat, G., Lambin, X., Lenzner, B., 2020. The role of species charisma in biological invasions. *Front. Ecol. Environ.* 18, 345–353.
- Jones, H.P., Holmes, N.D., Butchart, S.H.M., Tershy, B.R., Kappes, P.J., Corkery, I., Croll, D.A., 2016. Invasive mammal eradication on islands results in substantial conservation gains. *Proc. Natl. Acad. Sci. Unit. States Am.* 113, 4033–4038.
- Kalnicky, E.A., Brunson, M.W., Beard, K.H., 2014. A social-ecological systems approach to non-native species: habituation and its effect on management of coqui frogs in Hawaii. *Biol. Conserv.* 80, 187–195. <https://doi.org/10.1016/j.biocon.2014.09.044>.
- La Haye, M., 2019. Pallas' squirrel eradication in The Netherlands. In: Robinson, N., Shuttleworth, C. (Eds.), *Invasive Alien Species Colonisation Prevention: Your Guide to Early Detection and Rapid Response*. The Royal Society of Wildlife Trusts.
- La Morgia, V., Paoloni, D., Genovesi, P., 2017. Eradicating the grey squirrel *Sciurus carolinensis* from urban areas: an innovative decision-making approach based on lessons learnt in Italy. *Pest Manag. Sci.* 73, 354–363.
- Lioy, S., Marsan, A., Balduzzi, A., Wauters, L.A., Martinoli, A., Bertolino, S., 2019. The management of the introduced grey squirrel seen through the eyes of the media. *Biol. Invasions* 21, 3723–3733.
- Loy, A., Aloise, G., Ancillotto, L., Angelici, F.M., Bertolino, S., Capizzi, D., Amori, G., 2019. Mammals of Italy: an annotated checklist. *Hystrix* 30, 87–106.
- Manfredo, M.J., Teel, T.L., Henry, K.L., 2009. Linking society and environment: a multilevel model of shifting wildlife value orientations in the western United States. *Soc. Sci. Q.* 90, 407–427.
- Martinoli, A., Bertolino, S., Preatoni, D.G., Balduzzi, A., Marsan, A., Genovesi, P., Wauters, L.A., 2010. Headcount 2010: the multiplication of the grey squirrel populations introduced to Italy. *Hystrix* 21, 127–136.
- Merrick, M.J., Evans, K.L., Bertolino, S., 2016. Urban grey squirrel ecology, associated impacts and management challenges. In: Shuttleworth, C.M., Peter, L.W.W., Gurnell, J. (Eds.), *The Grey Squirrel: Ecology & Management of an Invasive Species in Europe*. European Squirrel Initiative, pp. 57–77.
- Miller, D.L., Burt, M.L., Rexstad, E.A., Thomas, L., 2013. Spatial models for distance sampling data: recent developments and future directions. *Methods Ecol. Evol.* 4, 1001–1010. <https://doi.org/10.1111/2041-210X.12105>.
- Niemiec, R.M., Pech, R.P., Norbury, G.L., Byrom, A.E., 2017. Landowners' perspectives on coordinated, landscape-level invasive species control: the role of social and ecological context. *Environ. Manag.* 59, 477–489.
- Ogden, J., Gilbert, J., 2009. Prospects for the eradication of rats from a large inhabited island: community based ecosystem studies on Great Barrier Island, New Zealand. *Biol. Invasions* 11, 1705–1717.
- Parkes, J., 1990. Eradication of feral goats on islands and habitat islands. *J. Roy. Soc. N. Z.* 20, 297–304.
- Perry, D.A.N., Perry, G.A.D., 2008. Improving interactions between animal rights groups and conservation biologists. *Conserv. Biol.* 22, 27–35.
- Piria, M., Copp, G.H., Dick, J.T.A., Duplić, A., Groom, Q., Jelić, D., Lucy, F.A., et al., 2017. Tackling invasive alien species in Europe II: threats and opportunities until 2020. *Management of biological invasions* 8 (3), 273–286.
- Robertson, P.A., Adriaens, T., Lambin, X., Mill, A., Roy, S., Shuttleworth, C.M., Sutton-Croft, M., 2017. The large-scale removal of mammalian invasive alien species in Northern Europe. *Pest Manag. Sci.* 73, 273–279.
- Robertson, P.A., Mill, A., Novoa, A., Jeschke, J.M., Essl, F., Gallardo, B., Pergl, J., 2020. A proposed unified framework to describe the management of biological invasions. *Biol. Invasions* 22 (9), 2633–2645.
- Romeo, C., McInnes, C.J., Dale, T.D., Shuttleworth, C., Bertolino, S., Wauters, L.A., Ferrari, N., 2018. Disease, invasions and conservation: No evidence of squirrelpox virus in grey squirrels introduced to Italy. *Anim. Conserv.* 22, 14–23.
- Santicchia, F., Wauters, L.A., Piscitelli, A.P., Van Dongen, S., Martinoli, A., Preatoni, D., Romeo, C., Ferrari, N., 2020. Spillover of an alien parasite reduces expression of costly behaviour in native host species. *J. Anim. Ecol.* 89, 1559–1569.
- Sarat, E., Mazaubert, E., Dutartre, A., Poulet, N., Soubeyran, Y., 2015. *Invasive Alien Species in Aquatic Environments. Practical Information and Management Insights*. Volume 2. Management Insights. Onema. Knowledge for action series.
- Saunders, A., Blaffart, H., Morley, C., Kuruyawa, J., Masibalavu, V., Seniloli, E., 2007. A “community” approach to invasive species management: some Pacific case studies. In: Witmer, G.W., Pitt, W.C., Fagerstone, K.A. (Eds.), *Managing Vertebrate Invasive Species: Proceedings of an International Symposium*. USDA/APHIS/WS, National Wildlife Research Center, Fort Collins, CO.
- Scapin, P., Urbano, M., Ruggiero, C., Balduzzi, A., Marsan, A., Ferrari, N., Bertolino, S., 2019. Surgical sterilization of male and female grey squirrels (*Sciurus carolinensis*) of an urban population introduced in Italy. *J. Vet. Med. Sci.* 81, 641–645.
- Schuchert, P., Shuttleworth, C.M., McInnes, C.J., Everest, D.J., Rushton, S.P., 2014. Landscape scale impacts of culling upon a European grey squirrel population: can trapping reduce population size and decrease the threat of squirrelpox virus infection for the native red squirrel? *Biol. Invasions* 16, 2381–2391.
- Seebens, H., Blackburn, T.M., Dyer, E.E., Genovesi, P., Hulme, P.E., Jeschke, J.M., Essl, F., 2017. No saturation in the accumulation of alien species worldwide. *Nat. Commun.* 8, 14435. <https://doi.org/10.1038/ncomms14435>.
- Shackleton, R.T., Shackleton, C.M., Kull, C.A., 2019. The role of invasive alien species in shaping local livelihoods and human well-being. *J. Environ. Manag.* 229, 145–157.
- Siebert, R., Toogood, M., Knierim, A., 2006. Factors affecting European farmers' participation in biodiversity policies. *Sociol. Rural.* 46, 318–340. <https://doi.org/10.1111/j.1467-9523.2006.00420.x>.
- Signorile, L.A., Reuman, D.C., Lurz, P.W.W., Bertolino, S., Carbone, C., Wang, J., 2016. Using DNA profiling to investigate human-mediated translocations of an invasive species. *Biol. Conserv.* 195, 97–105.
- Simberloff, D., Martin, J.L., Genovesi, P., Maris, V., Wardle, D.A., Aronson, J., Pyšek, P., 2013. Impacts of biological invasions: what's what and the way forward. *Trends Ecol. Evol.* 28, 58–66.
- Tompkins, D.M., Sainsbury, A.W., Nettleton, P., Buxton, D., Gurnell, J., 2002. Parapoxvirus causes a deleterious disease in red squirrels associated with UK population declines. *Proc. R. Soc. B* 269, 529–533.
- Unlu, I., Farajollahi, A., 2012. To catch a tiger in a concrete jungle: operational challenges for trapping *Aedes albopictus* in an urban environment. *J. Am. Mosq. Contr. Assoc.* 28, 334–337.
- Urgenson, L.S., Prozesky, H.E., Esler, K.J., 2013. Stakeholder perceptions of an ecosystem services approach to clearing invasive alien plants on private land. *Ecol. Soc.* 18. <https://doi.org/10.5751/ES-05259-180126> art26–13.
- Varnham, K., Glass, T., Stringer, C., 2011. In: Veitch, C.R., Clout, M.N., Towns, D.R. (Eds.), *Involving the community in rodent eradication on Tristan da Cunha, Island Invasives: Eradication and Management*. IUCN, Gland, Switzerland, pp. 504–507.

- Vimercati, G., Davies, S.J., Hui, C., Measey, J., 2017. Does restricted access limit management of invasive urban frogs? *Biol. Invasions* 19, 3659–3674.
- Wauters, L.A., Gurnell, J., Martinoli, A., 2002a. Interspecific competition between native Eurasian red squirrels and alien grey squirrels: does resource partitioning occur? *Behav. Ecol. Sociobiol.* 52, 332–341.
- Wauters, L.A., Tosi, G., Gurnell, J., 2002b. Interspecific competition in tree squirrels: do introduced grey squirrels (*Sciurus carolinensis*) deplete tree seeds hoarded by red squirrels (*S. vulgaris*)? *Behav. Ecol. Sociobiol.* 51, 360–367.