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It is time to ensure legal protection for non-protected native Italian small mammals

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Abstract

The Italian national law 157/1992 protects all species of mammals and birds, with the exception of rats, mice, voles and moles (totally 20 native species), which have been long considered responsible for the spread of human diseases and damage to crops, forests, and ecosystems. These species are also excluded from all Annexes of the Habitats Directive, leaving several small mammals without legal protection in Italy. Seven species are endemic or subendemic in Italy, with their distribution often limited to a few regions (e.g., *Microtus nebrodensis*, *M. brachycercus* and *Talpa romana*) or to threatened habitats (e.g., *Arvicola italicus*). In this work, we summarise open questions about the lack of protection for small Italian mammals and analyse their status in the country. In contrast to previous beliefs, our investigation showed that most non-protected rodents and moles play pivotal ecological roles in food chains, besides acting as environmental bioindicators and ecosystem-service providers. Three species are classified as Near Threatened in the Italian red list and other three are considered Data Deficient. The harvest mouse, *Micromys minutus*, is the only rodent whose risk of extinction has worsened over the past 10 years in Italy. Considering the high number of endemic and subendemic taxa, Italy has full responsibility for the conservation of its unique small mammal fauna, claiming their protection under both national and European regulations, and promoting research and monitoring campaigns to fill knowledge gaps on their biology, ecology, threats and ensure an adequate conservation status.

Keywords: Conservation, legislation, protection, Rodentia, Talpidae.

Introduction

The first step to ensure the conservation of species is to give them legal protection. National and international laws, directives, and agreements protect many species at different levels, forbidding or regulating their exploitation, trade, or even guaranteeing their total protection (Male and Bean, 2005; Mooers et al., 2007). In Europe, the Habitats Directive provides the highest level of protection for species (Directive 92/43/CEE, hereinafter HD). Species listed in Annex IV are strictly protected (art. 2); for those listed in Annex II, in addition to direct protection parts of their habitats are also protected as Special Areas of Conservation (SACs) included in the Natura 2000 network. The inclusion of a species in the HD aims to maintain them in a favourable conservation status. Species listed in Annex V may be exploited but are subject to management measures. Even species considered a priority for conservation and listed in Annexes II/IV, such as the case of the grey wolf (*Canis lupus*), may be regulated if there is no satisfactory alternative and management is not detrimental to the maintenance of populations at favourable conservation status (Epstein et al. 2019; European Commission 2021). Including a species in the HD implies that it must be monitored regularly, implementing conservation measures when necessary. As a result, most listed species have been the subject of sufficient research to provide knowledge for effective conservation measures. For instance, research efforts on the hazel dormouse (*Muscardinus avellanarius*), as measured by the number of published articles, increased significantly after its inclusion in the HD (Lang et al., 2022). On the other hand, research efforts on the garden dormouse (*Eliomys quercinus*), probably the European mammal that has lost the most significant proportion of its range in recent decades (Bertolino, 2017) but excluded by the HD, halved after the year 2000 (Lang et al., 2022).

At a more local (national) scale, the Italian national law n. 157/1992 declares as protected all mammals and birds present with populations within the national territories. However, moles, rats, mice and voles are explicitly excluded from this legal protection (art. 2.2). Nonetheless, the text of the law does not provide an exhaustive list of species for which control is allowed, and does not consider the diversity of these taxa and their species-specific conservation status. While rats (*Rattus*

spp.) and house mice (*Mus domesticus*) are considered as species introduced into the country, the other 20 species are native and, in some cases, endemic or subendemic (Bertolino et al., 2015; Loy et al., 2019). These species are regarded as agricultural pests, and the exclusion from protection aims at allowing their direct control without the need for authorization from local authorities, as instead foreseen for the other species (art. 19). For instance, different *Microtus* species are known to damage horticultural crops and orchards (Santini, 1983; Capizzi and Santini, 2007). However, the perception of the negative impact of these species as pests commonly overshadows their pivotal ecological roles. For example, seed-caching mice and voles are known to be involved in seed dispersal, thus positively affecting plant species' long-term survival and forest regeneration (Jensen and Nielsen 1986; Gómez et al. 2008). Small mammals are also a primary food source for many predators, influencing their population dynamics (Korpimäki and Norrdahl 1989; Byrom et al., 2014; Grendelmeier et al., 2018). This work aims to review the conservation status of Italian small mammals not protected by national laws, and provide data and arguments highlighting the urgent need for their protection.

Overview of native non-protected Italian small mammals

The national law N. 157/1992 excludes from protection the listed taxa twenty native species belonging to the family Talpidae (moles, three species), Cricetidae (voles, twelve species), and Muridae (mice, five species) (Table 1, Loy et al., 2019); other three murids – house mouse, black rat (*Rattus rattus*) and brown rat (*R. norvegicus*) – are introduced and thus are not considered here. Four non-protected species (*Talpa romana*, *Arvicola italicus*, *Microtus nebrodensis* and *Microtus brachycercus*) are endemic to Italy. Three specis (*Talpa caeca*, *Microtus multiplex*, and *Microtus savii*) are subendemic, as most of their range is limited to Italy, extending to neighbouring countries for a small part (Loy et al., 2019). Therefore, for these species, Italy is responsible for their long-term survival. According to the most recent Italian red list (Rondinini et al., 2022; Table 1), *Arvicola italicus*, *Chionomys nivalis*, and *Micromys minutus* are classified as Near Threatened, while

Apodemus alpicola, *Arvicola amphibius*, and *Talpa caeca* are considered Data Deficient indicating an insufficient knowledge to assess their status. *Micromys minutus* is the only rodent species that has seen its status worsen from the previous assessment 10 years earlier, when it was rated as Least Concern (Rondinini et al., 2013; Table 1).

An overview of these species is presented below, with comments on their respective conservation status and a focus on knowledge gaps.

Talpa caeca, *T. romana*, *T. europaea*

Italy hosts three species of moles, with remarkable differences in their extent of occurrence and degree of population fragmentation (Amori et al., 2008). The Eurasian common mole *T. europaea* occurs in northern and nentral Italy; the larger and more robust Roman mole *T. romana* is endemic to south-central Italy and parapatric to *T. europaea*; and the small-sized blind mole *T. caeca*, occurs in the Balkans and Italy with a discontinuous and fragmented distribution. In Italy, this species is sympatric but rarely syntopic to both *T. romana* and *T. europaea*, whereas, in the Balkans, it co-occurs with *T. stankovici* and *T. europaea*. Recent molecular investigations suggest mole diversity in Europe and Italy might be even higher. The Italian lineage of *T. caeca* was found distinct from the Balkan lineage (Colangelo et al., 2010). The time of divergence of the two main lineages within *T. caeca* was estimated to be at least 1 Mya, a value close to the maximum limit of intraspecific divergence (Bannikova et al., 2015). Similarly, the Italian lineage of *T. europaea* is genetically well distinct from the European lineage (Feuda et al., 2015). Also in this case the separation of the two lineages was dated before the onset of the main Pleistocene glaciations (approximately 0.7 Mya), a separation time suggesting a long and independent evolution of the Italian clade. According to the level of genetic divergence observed, the apparent restriction of geneflow and, in the case of *T. caeca* the clearly disjunct distribution, both the Italian lineage of *T. caeca* and *T. europaea* can be considered as putative Evolutionary Significant Units (ESU; Moritz, 1994) waiting for further investigations to fully understand the extent and significance of their diversity respect to their respective conspecific

lineages. Despite this high diversity and biogeographic complex interactions, all Italian moles are still considered pests, thus lacking legal protection. This is related to a common belief that moles damage gardens and crops and to the conviction that they are still widespread. However, both beliefs are false and misleading. First, it should be underlined that moles are strictly insectivores and do not feed on any plant material, fruits, flowers, or roots (Amori et al. 2008). Thus, their negative impact on gardens and crops should only be evaluated in relation to the tunnels that might alter the irrigation systems and molehills that may occur on well-kept lawns and, for example, golf courses, as well as horse racing courses.

Population size and abundance of moles are challenging to estimate, and the only available data derive from indirect signs of species occurrence, i.e., the typical molehills. However, molehills cannot be distinguished among species. Whereas they can relatively easily be attributed to one of the two parapatric species based on their location, i.e., *T. europaea* in north-central and *T. romana* in south-central Italy, the occurrence of the scattered *T. caeca* is far less easy to detect, being this species either allopatric or sympatric to both *T. europaea* and *T. romana*. Moreover, the common belief that in Italy *T. caeca* is restricted and specialised to live at the highest altitudes of the Alps and the Apennine Mountain chains has been recently questioned by Loy et al. (2017), stressing the low knowledge of the actual status of blind mole populations in Italy. Considering the scanty distributional data, there is the urgent need for a systematic survey of *T. caeca* and *T. romana* in Italy.

Arvicola italicus and *Arvicola amphibius*

Molecular and morphometric studies indicated that the Italian water vole *Arvicola italicus* is a species distinct from other European water vole populations (Castiglia et al., 2016). It is, therefore, an endemic species distributed in continental Italy. Despite a potentially wide area of distribution, available records are limited, and there are indications of population decline at the local level (Castiglia et al., 2016). The European water vole *Arvicola amphibius* is reported only for the north-eastern part of the country.

European water voles are widespread, but populations are declining in some countries, particularly in Great Britain, where it is considered one of the most endangered mammals (Mathews et al., 2018). The species' decline is connected to the loss of wetlands after agriculture intensification and urbanisation expansion (Jefferies et al., 1989; Dean et al., 2016). A further threat is represented by the introduced American mink (*Neovison vison*), which predates water voles and induces the fragmentation of residual populations (Aars et al., 2001). The same threats are present in Italy. Wetlands are declining, the American mink is present with established populations in northern and central Italy (Loy et al., 2019), and the Italian water vole is one of its main preys (Mori and Mazza, 2019).

A further conservation issue is the use of rodenticides, commonly used against the Norway rat *Rattus norvegicus*, which often inhabits riparian habitats, but also against coypu *Myocastor coypus*, although illegally. This threat could explain the scarcity of both *Arvicola* species or their disappearance in suburban and agricultural areas, where they were once widespread (Capizzi and Santini, 2007).

Chionomys nivalis

Referring to the principle of priority, Kryštufek et al. (2022) considered *Chionomys syriacus* the valid name combination for the European snow vole. To fix the nomenclature, the authors sent an application to the International Commission on Zoological Nomenclature (Case 3859), which is still under evaluation. The European snow vole is a microtine rodent considered a glacial relict which depends on the fractured rocky substrate (Krystufek and Shenbrot, 2022) and is a good bioindicator in mountain environments (Metcheva et al., 2008). Castiglia et al. (2009) found six distinct molecular lineages of the European snow vole, two of which exclusive of the Italian peninsula and distinct from other lineages by a large number of mutations. The species is common in the Alps and rare and localised in the Apennines (Janeau and Aulagnier, 1997; Amori et al., 2008). The snow vole inhabits rocky areas not only at high altitudes but is also found at sea level. Its ecological niche is represented by petricolic soils, primarily in mid- and high-mountain environments. These soils, at high altitudes,

mitigate the effects of strong temperature fluctuations both during the day and throughout the seasons and allow the snow vole to live in habitats with severe temperatures (Nappi, 2002; Luque-Larena et al. 2002).

The species is listed as "Near Threatened" in the Italian red list (Rondinini et al. 2022; Tab. 1); however, little is known about populations in central-southern Apennine (Amori et al., 2008). The snow vole has an intrinsic sensitivity to global changes: 1) it is strictly herbivorous and predominantly uses high-altitude grasslands as foraging areas; 2) in Italy, it has a limited distribution range; 3) it is mainly adapted to extreme environments. Due to its ecological specialisation, it is potentially vulnerable to habitat changes (Yoccoz and Ims, 1999; Bertolino et al. 2014). In this regard, studies have highlighted that climate change will be more intense and rapid in high-altitude areas, leading to an upward shift in vegetation due to global warming (Vitasse et al., 2021). Moreover, land-use change processes affect the foothill and montane zones, especially in the Italian Alps. In these areas, attention should be focused on preserving its prime habitat characterised by petricolous soils.

Microtus species

The Italian voles of the genus *Microtus* have undergone a major revision in recent years, with new taxa identified (see Galleni et al., 1994; Castiglia et al., 2008). The first group to be examined comprised species with a distinctly fossorial abit, sometimes included in the subgenus *Terricola* (Carleton and Musser, 2005). This group is the most significant for Italy in terms of both distribution and number of species, some of which are endemic or subendemic. These species are often the target of control actions in agricultural contexts due to significant economic damage to orchards (especially apple and citrus orchards) and horticultural crops (severe damage was found in artichoke stands in southern Italy). The most important damage is done by *Microtus savii* (Caroli et al., 2000; Ranchelli et al., 2016). However, given the recent subdivision of the taxon into at least three distinct species (*M. savii* present in northern and central Italy, *M. brachycercus* southern and central Italy, and *M. nebrodensis* Sicily), the damage must be attributed to the appropriate species, depending on the area

in which it occurs. Other species in this group (*M. multiplex*, *M. liechteinsteini*, and *M. subterraneus*) are of no economic importance, partly because of relatively limited distribution. However, it must be considered that the distinction of these species by external morphology alone is difficult: therefore, protection should be extended to all species. Similar considerations apply to the species in the second group, which exhibit more superficial activity, sometimes included in the subgenus *Microtus*, namely *Microtus arvalis* and *M. levernedii*. Their economic impact is somewhat limited, and their distinction is also rather difficult from the external morphology. These damages, often economically significant, have justified control activities in the past, conducted mainly with anticoagulant rodenticides (Capizzi et al., 2014). Results, however, are not always satisfactory in terms of damage reduction (Capizzi and Santini, 2007). Furthermore, the use of rodenticides carries significant risks of secondary intoxication for the voles' numerous predators (mainly carnivores and nocturnal and diurnal raptors, e.g. carnivores, Oliva-Vidal et al., 2022, owls, Bertolino et al., 2001). These applications have significantly decreased following regulatory revisions on biocide use in recent years. Most *Microtus* species do not have conservation risks, being common and widespread in agroforestry ecosystems, open areas and pastures, sometimes beyond the limit of forest vegetation (Temple and Terry, 2007). For some Italian species, however, data are quite limited (Amori et al., 2008). Nevertheless, it is believed that their protection would have little impact on agricultural activities, as i) the application of rodenticides is time-consuming and their use is limited despite the intensity of damage, and ii) rodenticides patented for use against voles have almost disappeared from the market. In conclusion, we stress that the protection of microtines would have a positive effect on predators by reducing the risk of secondary intoxication, with minor (or no) economic consequence on agricultural practices.

Clethrionomys glareolus (*Myodes glareolus*)

Two genera (*Clethrionomys* and *Myodes*) have been used to identify the bank vole; recently, Kryštufek et al. (2022) supported the need to return to the old *Clethrionomys glareolus*. The species is widespread throughout most of Europe’s temperate climate and boreal forests (Amori et al., 2008).

The species inhabits broadleaved and coniferous woodlands, from plains up to 2,300 metres in the mountains, tree scrub, parks, hedgerows. It has no economic impact on human activities, neither on field crops nor on orchards (Capizzi and Santini, 2007). In the Italian Peninsula, there are five distinct evolutionary lineages: one widespread between the Alps and northern Italy, one distributed mainly throughout the north and central Apennines, a slightly differentiated lineage restricted to the Apulian region (Gargano promontory), and an high differentiated lineage in Calabria region (Colangelo et al., 2012; Chiocchio et al., 2019) where there are two distinct subspecies: *M. glareolus curcio* in the Sila Massif and *M. glareolus hallucalis* in the Aspromonte Massif (Amori et al., 2008). The Calabrian clade is characterised by a strong ancient (early Pleistocene) genetic isolation and divergence (based on mtDNA) from all other *M. glareolus* lineages (Colangelo et al., 2012; Filipi et al., 2015). Therefore, the Calabrian lineage could be considered as an ESU, deserving particular attention (Colangelo et al, 2010; Chiocchio et al., 2019). This lineage identified in southern Italy pose a conservation issue linked to the need to protect taxa below the species level (but close to the interspecific boundary), that have a restricted distribution.

Apodemus agrarius, *A. sylvaticus* and *A. flavicollis*

The striped field mouse *A. agrarius* exhibits the most extended distribution range of the genus *Apodemus*, with an extensive but disjunct range covering almost the entire Palearctic, divided by the dry and mountainous areas of central Asia (e.g., Mongolia). Nonetheless, extensive sampling across the whole range confirmed that the species is likely to represent a single taxon (Kareseva et al., 1992, Yalkovskaya et al., 2022). The wood mouse *A. sylvaticus* and the yellow-necked mouse *A. flavicollis* are mostly present in the western Palearctic, with large ranges extending throughout Europe. None of these species have any economic impact on human activities, with the exception of limited local impacts on forest sowings and nurseries (Capizzi and Santini, 2007).

In Italy, *A. agrarius* shows a relatively small range restricted to north-eastern regions and an apparently isolated population in Lombardy (Loy et al., 2019), whereas *A. sylvaticus* and *A. flavicollis*

are widespread in the whole Peninsula, although the yellow-necked mouse is absent from the most urbanised and intensively cultivated areas. The wood mouse is also present in both major and some minor islands. The Sicilian population of the wood mouse appears to be genetically very differentiated and highly variable with respect to other populations (Michaux et al., 2003). This emphasises the importance of Sicily as a 'hot spot' for the wood mouse's intraspecific genetic diversity and suggests this taxon could require taxonomic revision.

From a conservation perspective, high-resolution genetic sampling indicates that *A. agrarius* is sensitive to urbanisation (Gortat et al., 2015) as, despite its ability to persist in cities across Europe (Santini et al., 2019), urban populations are genetically isolated and thus more prone to local extinction. *Apodemus agrarius* also occurs in agricultural landscapes, where its populations are favoured by organic management practices and the maintenance of more complex landscape structures such as hedgerows and tree lines (Fischer et al., 2011). Similarly, *A. sylvaticus* is also favoured by the maintenance of landscape complexity (e.g., Fischer et al., 2011, Panzacchi et al., 2010), and restoration of semi-natural habitats can represent a significant environmental measure for the species' conservation in agricultural landscapes (Balestrieri et al., 2017). Moreover, the wood mouse appears to be potentially affected by urbanisation, showing low adaptability to highly artificial habitats, thus underlying the need to preserve natural areas within urban environments (Gomes et al., 2011). Unlike *A. agrarius* and *A. sylvaticus*, *A. flavicollis* is more strictly associated with wooded areas and is commonly known as a forest specialist. The species generally tolerates moderate wooded habitat loss and fragmentation (Marsh et al., 2001; Lešo et al., 2014; Sozio and Mortelliti, 2015). Forest management seems to have a controversial role in affecting the occurrence, population density and survival of the species, with effects depending on the intensity and the type of silvicultural practices, e.g., clear-cutting, coppicing, artificial plantation (Capizzi and Luiselli, 1996; Lešo et al., 2014; Gasperini et al., 2016). Finally, *A. flavicollis* is susceptible to agricultural land use intensification (Gentili et al., 2014). Although urbanisation and replacement of natural habitats with cropland are present in Italy, where forest management and silvicultural practices are also widely

applied, the ecological and biological traits of *A. agrarius*, *A. sylvaticus* and *A. flavicollis*, together with their current distributions, suggest that these species are unlikely to become threatened in Italy in the near future. However, knowledge gaps on species' distributions and local population trends persist, particularly for *A. agrarius*, and should be filled to provide a more informed assessment of their conservation status.

Apodemus alpicola

The Alpine wood mouse *Apodemus alpicola* was considered a subspecies of *A. flavicollis* until the 1980s, when it was recognised as a new species (Vogel et al., 1991). It has a relatively small range being endemic to the Alps (Reutter et al., 2002). The species prefers open forests and prairies at high elevations (mostly over 800 m and up to 2,400 m a.s.l., Debernardi et al., 2003). *Apodemus alpicola* is considered an ecologically specialised taxon among wood mice (Reutter et al., 2003), significantly sensitive to deviations from its optimal environmental conditions., e.g., in terms of climate and land cover. Such specialisation, together with the small global range, led some authors to consider the species a conservation priority (Bertolino et al. 2014). Italy has a great responsibility in securing the conservation of Alpine organisms since about 25% of the Alps falls within the Italian territory. Moreover, alpine mammals are especially exposed to climate change since this disproportionately affects high-altitude organisms worldwide (Pacifici et al., 2018). *Apodemus alpicola* is currently listed as Data Deficient by the Italian red list, a category that reflects uncertainty in its conservation status and calls for caution in assessing its risk of extinction. Given its probable sensitivity to warming temperatures, the species will likely undergo range shifts and contractions, thus deserving careful future attention – possibly including legal protection – to secure its conservation. Moreover, Maiorano et al. (2006) indicate that the species is currently poorly covered by the national network of protected areas, evidencing an underrepresentation of this taxon in recent conservation planning, e.g., due to the exclusion of the species from any Annex of the Habitats Directive. Given the difficulties in field identification of *A. alpicola* when in sympatry with congeneric species, it is also necessary to clarify

the species' actual distribution across the Alps and establish effective methods for its correct identification (Ancillotto et al., 2017). In conclusion, the extreme similarity of the species of the genus *Apodemus*, along with their limited or no impact on human activities, reinforces the need to ensure legal protection for all species of the genus.

Micromys minutus

The harvest mouse *Micromys minutus* is the smallest European rodent with a wide extent of occurrence ranging from northern Spain to Japan throughout the Palearctic. Disjunct ranges occur in northern Russia, with insular populations in the United Kingdom, Japan and Taiwan, whereas Chinese populations are currently ascribed to a different species, the Indochinese harvest mouse *Micromys erythrotis* (Yasuda et al. 2005). Phylogeographic analyses detected only four divergent clades: the European, the Korean-Japanese, the Taiwanese and the Russian (Yasuda et al., 2005; Mori et al., 2022). However, a focus on Italian samples indicated that the populations from the Po Plain are somewhat differentiated, representing a possible fifth clade (Mori et al., 2022). The harvest mouse has no impact on human activities (Capizzi and Santini, 2007) and is declining throughout its range following habitat loss due to climate change and habitat modification (Darinot et al., 2021; Mori et al., 2022).

The species is widely distributed in the Po Valley in wetlands of good quality, even if there is no data on population trends. In central Italy, there are only a few records, probably representing populations left isolated by the progressive reduction of favourable habitats (Amori et al., 2008; Mori et al., 2022). Field data and distribution models show that *M. minutus* is strictly linked to grasslands and wetlands and threatened by summer droughts, forest re-expansion and intensive monocultures (Amori et al., 2008; Sawabe and Natuhara, 2016). These pressures are present in northern Italy, where populations are primarily concentrated. A monitoring plan is therefore urgently needed.

Discussion

Italian law 157/1992 protects mammal and bird species with populations living permanently or temporarily in a state of natural freedom in the national territory (art. 2.1), except moles, rats, mice and voles, which are explicitly excluded from protection (art. 2.2). Thus, according to art 2.1, until recently homeothermic species introduced and established in the country were automatically protected by law, while twenty native mammal species lacked protection. Only recently has the law been amended to specify that the management of introduced species is aimed at eradication or population control (national law 28 dicembre 2015, n. 221, article 7.5). The original text of the law without modifications reflects the dominant attitude in the 1980s, when the problems associated with the introduction of species were not yet evident, at least in Italy. On the other hand, some species have been excluded from protection due to a perception of their negative impact on crops and human well-being.

Some *Microtus* species are sometimes responsible for damage to crops and vegetables by root gnawing and plant consumption (Capizzi and Santini, 2007). For this reason, all voles have been excluded from the protection to allow control by farmers without the need for the activation of a control plan by local authorities required for the management of protected species. All Talpidae have been excluded from the protection for the same reason, although, being insectivores, these species do not damage crops and other vegetables. It was, therefore, a misunderstanding of their diet and ecological role (cf. Atkinson et al., 1994). However, molehills in gardens and public green areas are considered aesthetically unattractive, and they may act as sites for weed and vole invasions, causing soil degradation (Edwards et al., 1999). *Rattus* spp. and *Mus domesticus* are introduced species and global pests with negative impacts in urban and agricultural areas and human well-being (Capizzi et al., 2014). The unfortunate use in the legislation of the term '*topi propriamente detti*' (i.e., 'mice proper') referred to these species has effectively extended the non-protection to all Muridae. In the end, only some *Microtus* species (i.e., of the *Microtus savii* group) are responsible for the damage to

agriculture among native small mammals since damage is not reported for Talpidae and native Muridae. Since damage is localised and rodenticides patented against voles have almost disappeared from the market, rodents' protection would have minimal consequences on agricultural activities. On the other hand, reducing the use of rodenticides minimises the risk of secondary poisoning of their predators.

Carnivora, such as *Canis lupus*, *Vulpes vulpes*, *Martes martes*, *Mustela putorius*, *Lutra lutra*, and *Felis silvestris*, were considered noxious by Italian law before the entry into force of law 968/1978, later replaced by law 157/1992. Nowadays, predators are protected by law, and some are even defined as particularly protected, with higher penalties for poaching. This change in legislation reflects how species are perceived by society: with predators considered apex species in ecosystems and not anymore as competitors of humans for prey (e.g., domestic and wild ungulates for wolves and fish for otters), though conflicts are still present (Morehouse and Boyce 2017; Davoli et al., 2022).

A society that does not consider Carnivora noxious species can further protect all native species. While protection should be extended to native species in general, we refer here only to those small mammals not covered by law 157/1992. Among these small mammals, seven species out of twenty (35%) are endemic or subendemic, for which Italy has full responsibility for their conservation. Furthermore, both the Italian lineage of *T. caeca* and *T. europaea* and the Calabrian lineage of C. *glareolus* could be considered as Evolutionary Significant Units and therefore worthy of protection. There is a widespread perception that small mammals do not need protection since they would not be subject to the risk of decline due to their r-type reproductive strategy (Bertolino et al., 2014). However, this depends more on the lack of data than on an actual assessment of population trends. In the IUCN European Mammal Assessment, demographic trend information was unavailable for 33% of the species considered, mostly small and medium sized (Temple and Terry, 2007). The Italian red list classified three non-protected rodent species as Near Threatened (Rondinini et al., 2022). Three other species are considered Data Deficient because the information available is so scarce that it has yet to be possible to assess their conservation status. The lack of a protection regime also results in

less funding and research on these species, perceived as harmful and not worthy of further study if not related to their management (Bertolino et al., 2015; Lang et al., 2022).

In Table 2, we report the legal situation of rodents and moles in some European countries. Muridae and Cricetidae among rodents and Talpidae are often not protected, a situation partly similar to Italy. In the Czech Republic, all mammals are protected by law, but other acts allow for controlling some rodents for veterinary or agricultural reasons. Similarly, in Poland, *Arvicola* and *Talpa* species are not protected in gardens, orchards and forest nurseries. In Great Britain, moles and some rodents are not protected. However, the water vole *A. amphibius*, a species with a Palearctic distribution, is becoming rare in the country and is considered as a flagship species for conservation. The species has declined mainly due to habitat loss, wetlands degradation, industrialisation of agriculture, and predation by American mink (Strachan and Moorhouse, 2006). For this reason, it is monitored throughout the country within a large-scale citizen science project (McGuire, 2021). Large breeding populations will then be included in a national network of key sites where habitats will be managed appropriately. By contrast, the endemic Italian water vole is not protected, the distribution and population trends are unknown and there is no national or regional monitoring project. A partly similar situation is present in Spain for the Southwestern water vole (*Arvicola sapidus*). This species is protected and listed as Vulnerable in Valencia and Catalonia regions, but it is not protected at all in Andalucia or Extremadura (Adrià Viñals Domingo pers. com.).

Between non-protected Italian small mammals, there are endemic or subendemic species, species clearly declining or for which it is impossible to define the status due to the extreme lack of distributional data. There is no reason not to consider them as protected as other mammals. It is, therefore, time to give these species the legislative protection they deserve, removing from art. 2.2 of the Law 157/1992 the words '*le norme della presente legge non si applicano alle talpe, ai ratti, ai topi propriamente detti, alle arvicole*' (i.e., 'the provisions of this law do not apply to moles, rats, mice proper, and voles'). In general, the difficulty for the non-experts (e.g. private citizens, home and business owners, farmers, etc.) of distinguishing the various small mammal species should not

be a justification for providing for a generalised possibility of their control, but, on the contrary, for providing for their protection.

A discussion could be open on protecting species of the *savii* group (*M. savii*, *M. brachycercus*, *M. nebrodensis*). These small mammal species produce damage to agriculture but are also endemic or sub-endemic and, therefore, of conservation relevance to Italy. The difficulty of distinguishing these species from other Microtus (i.e. *M. multiplex* and *M. subterraneus*), along with their lower damage compared to previous decades, makes it possible to evaluate the protection of these animals, which could in any case be subject to control according to the procedures laid down by law for all other mammal species.

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References

Aars J., Lambin X., Denny R., Griffin A.C., 2001. Water vole in the Scottish uplands: distribution patterns of disturbed and pristine populations ahead and behind the American mink invasion front. Anim. Conserv. 4:187–194. Doi: 10.1017/S1367943001001226

Amori G., Contoli L., Nappi A., 2008. Fauna d'Italia, Mammalia II: Erinaceomorpha, Soricomorpha, Lagomorpha, Rodentia. Calderini editions, Bologna, Italy.

Ancillotto L., Mori E., Sozio G., Solano E., Bertolino S., Russo D., 2017. A novel approach to field identification of cryptic *Apodemus* wood mice: calls differ more than morphology. Mammal Rev. 47(1): 6-10. Doi: 10.1111/mam.12076.

Atkinson R.P.D., Macdonald D.W., Johnson P.J., 1994. The status of the European mole *Talpa europaea* L. as an agricultural pest and its management. Mammal Rev. 24(2):73-90.

Balestrieri A., Remonti L., Morotti L., Saino N., Prigioni C., Guidali F., 2017. Multilevel habitat preferences of *Apodemus sylvaticus* and *Clethrionomys glareolus* in an intensively cultivated agricultural landscape. Ethol. Ecol. Evol. 29(1):38-53.

Bannikova A.A., Zemlemerova E.D., Colangelo P., Sözen M., Sevindik M., Kidov A.A., Dzuev R.I., Kryštufek B., Lebedev V.S. 2015. Nuclear Phylogeny and Genetic Diversity of *Talpa*. Zool. J. Linn. Soc., 175: 930-948.

Bertolino S., 2017. Distribution and status of the declining garden dormouse *Eliomys quercinus*. Mammal Rev. 47(2), 133-147.

Bertolino, S., Ghiberti, E., & Perrone, A. (2001). Feeding ecology of the long-eared owl (*Asio otus*) in northern Italy: is it a dietary specialist? Can. J. Zool. 79: 2192-2198.

Bertolino S., Girardello M., Amori G., 2014. Identifying conservation priorities when data are scanty: a case study with small mammals in Italy. Mammal. Biol. 79:349-356. Doi: 10.1016/j.mambio.2014.06.006

Bertolino S., Colangelo P., Mori E., Capizzi D., 2015. Good for management, not for conservation: an overview of research, conservation and management of Italian small mammals. Hystrix It. J. Mamm. 26(1): 25–35.

Byrom A.E., Craft M.E., Durant S.M., Nkwabi A.J., Metzger K., Hampson K., ... Sinclair A.R.E., 2014. Episodic outbreaks of small mammals influence predator community dynamics in an east African savanna ecosystem. Oikos 123: 1014-1024.

Capizzi D., Luiselli L., 1996. Ecological relationships between small mammals and age of coppice in an oak-mixed forest in central Italy. Rev. Ecol. (Terre et Vie) 51:277–291.

Capizzi D., Santini L., 2007. I Roditori Italiani: ecologia, impatto sulle attività umane e sugli ecosistemi, gestione delle popolazioni. Antonio Delfino editions, Roma, Italy.

Capizzi D., Bertolino S., Mortelliti A., 2014. Rating the rat: global patterns and research priorities in impacts and management of rodent pests. Mammal Rev. 44: 148-162. Doi: 10.1111/mam.12019

Carleton M.D., Musser G.G., 2005. Order Rodentia. In: Wilson D.E., Reeder D.M. (Eds.) Mammal species of the world: a taxonomic and geographic reference (2 voll.). Johns Hopkins University Press, Baltimora, Maryland. 745-753.

Caroli L., Capizzi D., Luiselli L., 2000. Reproductive strategies and life-history traits of the Savi's Pine Vole, *Microtus savii*. Zool. Sci. 17: 209-216. Doi: 10.2108/zsj.17.209

Castiglia R., Annesi F., Aloise G., Amori G., 2008. Systematics of the *Microtus savii* complex (Rodentia, Cricetidae) via mitochondrial DNA analyses: paraphyly and pattern of sex chromosome evolution. Molec. Phylogen. Evol. 46: 1157-1164. Doi: 10.1016/j.ympev.2007.12.005

Castiglia, R., Annesi, F., Kryštufek, B., Filippucci, M.G., Amori, G. 2009. The evolutionary history of a mammal species with a highly fragmented range: the phylogeography of the European snow vole. Journal of Zoology, 279: 243-250.

Castiglia R., Aloise G., Amori G., Annesi F., Bertolino S., Capizzi D., Mori E., Colangelo P., 2016. The Italian peninsula hosts a divergent mtDNA lineage of the water vole, *Arvicola amphibius* sl, including fossorial and aquatic ecotypes. Hystrix It. J. Mamm. 27(2): 99–103.

Chiocchio A., Colangelo P., Aloise G., Amori G., Bertolino S., Bisconti R., Castiglia R.,Canestrelli D., 2019. Population genetic structure of the bank vole *Myodes glareolus* within its glacial refugium in peninsular Italy. J. Zool. System. Evol. Res. 57(4):959-969. Doi: 10.1111/jzs.12289

Colangelo P., Bannikova A.A., Kryštufek B., Lebedev V., Annesi F., Loy A., Capanna E., 2010. Molecular Systematic and evolutionary biogeography of the genus *Talpa* (Soricomorpha: Talpidae). Molecular Phylogenetics and Evolution 55: 372–380.

Colangelo P., Aloise G., Franchini P., Annesi F., Amori G., 2012. Mitochondrial DNA reveals hidden diversity and an ancestral lineage of the bank vole in the Italian Peninsula. J. Zool. 287:41– 52. Doi:10.1111/j.1469-7998.2011.00884.x

Darinot F., Le Petitcorps Q., Arnal V., Coulon A., Montgelard C., 2021. Effects of landscape features and flooding on the genetic structure of a small wetland rodent, the harvest mouse (*Micromys minutus*). Landsc. Ecol. 36(6):1755-1771. Doi: 10.1007/s10980-021-01235-5

Davoli M., Ghoddousi A., Sabatini F.M., Fabbri E., Caniglia R., Kuemmerle T. 2022. Changing patterns of conflict between humans, carnivores and crop-raiding prey as large carnivores recolonize human-dominated landscapes. Biol. Conserv. 269, 109553.

Dean M., Strachan R., Gow D., Andrews R., 2016. The Water Vole Mitigation Handbook (The Mammal Society Mitigation Guidance Series). Mathews F., Chanin P. (Eds.). London: The Mammals Society.

Debernardi P., Patriarca E., Reutter B., 2003. Contribution to the knowledge of *Apodemus* genus in the Gran Paradiso National Park. Hystrix 14:55-75. Doi: 10.4404/hystrix-14.1-2-4316

Edwards G.R., Crawley M.J., Heard M.S., 1999. Factors influencing molehill distribution in grassland: implications for controlling the damage caused by molehills. J. Appl. Ecol. 36: 434-442. Doi: 10.1046/j.1365-2664.1999.00411.x

Epstein Y., Christiernsson A., López-Bao J. V., Chapron G., 2019. When is it legal to hunt strictly protected species in the European Union?. Conserv. Sci. Practice 1: e18. Doi:10.1111/csp2.18

European Commission (2021) Guidance document on the strict protection of animal species of Community interest under the Habitats Directive 92/43/EEC. www.ec.europa.eu/environment/nature/conservation/species/guidance/index_en.htm

Feuda R., Bannikova A.A., Zemlemerova E.D., Di Febbraro M., Loy A., Hutterer R., Aloise G., Zykov A.E., Annesi F., Colangelo P., 2015, Evolutionary History of the Mole. Biol J Linn Soc Lond, 114: 495-512.

Filipi K., Marková S., Searle J.B., Kotlík P., 2015. Mitogenomic phylogenetics of the bank vole *Clethrionomys glareolus*, a model system for studying end-glacial colonisation of Europe. Molec. Phylogen. Evol. 82:245–257. Doi:10.1016/j. ympev.2014.10.016

Fischer C., Thies C., Tscharntke T., 2011. Small mammals in agricultural landscapes: opposing responses to farming practices and landscape complexity. Biol. Conserv. 144(3):1130-1136. Doi: 10.1016/j.biocon.2010.12.032

Galleni L., Tellini A., Stanyon R., Cicalò A., Santini L., 1994. Taxonomy of *Microtus savii* (Rodentia, Arvicolidae) in Italy: cytogenetic and hybridisation data. J. Mammal.75: 1040-1044. Doi: 10.2307/1382487.

Gasperini S., Mortelliti A., Bartolommei P., Bonacchi A., Manzo E., Cozzolino R., 2016. Effects of forest management on density and survival in three forest rodent species. For. Ecol. Manag. 382:151-160.

Gentili S., Sigura M., Bonesi L., 2014. Decreased small mammal species diversity and increased population abundance along a gradient of agricultural intensification. Hystrix 25(1):39-44. Doi:10.4404/hystrix-25.1-9246

Grendelmeier A., Arlettaz R., Pasinelli G. 2018. Numerical response of mammalian carnivores to rodents affects bird reproduction in temperate forests: A case of apparent competition?. Ecol. Evol. 8: 11596-11608.

Gomes V., Ribeiro R., Carretero M.A., 2011. Effects of urban habitat fragmentation on common small mammals: species versus communities. Biodivers. Conserv. 20(14):3577-3590.

Gómez J.M., Puerta-Piñero C., Schupp E.W. 2008. Effectiveness of rodents as local seed dispersers of Holm oaks. Oecologia 155: 529-537.

Gortat T., Rutkowski R., Gryczyńska A., Pieniążek A., Kozakiewicz A., Kozakiewicz M., 2015. Anthropopressure gradients and the population genetic structure of *Apodemus agrarius*. Conserv. Gen. 16(3):649-659. Doi: 10.1007/s10592-014-0690-0

Janeau G., Aulagnier S., 1997. Snow vole— *Chionomys nivalis* (Martins 1842). J. Mountain Ecol. 4:e11

Jefferies D.J., Morris P.A., Mulleneux J.E., 1989. An enquiry into the changing status of the Water Vole *Arvicola terrestris* in Britain. Mamm. Rev. 19: 111–131.

Jensen T.S., Nielsen O.F. 1986. Rodents as seed dispersers in a heath-oak wood succession. Oecologia 70: 214-221.

Karaseva E.V., Tikhonova G.N., Bogomolov P.L., 1992. Distribution of the Striped field mouse (*Apodemus agrarius*) and peculiarities of its ecology in different parts of its range. Zoologičeskij Zurnal 71(6):106-115.

Korpimäki E., Norrdahl K. 1989. Avian predation on mustelids in Europe 2: impact on small mustelid and microtine dynamics: a hypothesis. Oikos 55: 273-276.

Kryštufek B., Shenbrot G.I., 2022. Vole and Lemmings (Arvicolinae) of the Palaearctic Region. University Maribor, University Press. Doi: 10.18690/um.fnm.2.2022

Kryštufek B., Shenbrot G., Janžekovič F., 2021. Long-standing taxonomic confusion over the identity of Hypudaeus syriacus Brants, 1827, at last resolved. Mammalia 85: 603-611.

Kryštufek B., Tesakov A.S., Lebedev V.S., Bannikova A.A., Abramson N.I., Shenbrot G., 2022. Back to the future: The proper name for red-backed voles is *Clethrionomys* Tilesius and not *Myodes* Pallas. Mammalia 84, 214–217.

Lang J., Büchner S., Meinig H., Bertolino S., 2022. Do we look for the right ones? An overview of research priorities and conservation status of dormice (Gliridae) in Central Europe. Sustainability 4(15):9327. https://doi.org/10.3390/su14159327

Lešo P., Lešová A., Kropil R., 2014. Influence of forest fragmentation on the distribution of small terrestrial mammals in fir-beech commercial forest. J. For. Sci. 60(8):324-329.

Loy A., Cassini M. H., Colangelo P., Di Febbraro M., 2017. Distribution, spatial interaction and niche analysis in three species of European moles (genus *Talpa*, Soricomorpha: Mammalia). Biol. J. Linnean Soc. 122(4): 872-882. Doi: 10.1093/biolinnean/blx085

Loy A., Aloise G., Ancillotto L., Angelici F.M., Bertolino S., Capizzi D., Castiglia R., Colangelo P., Contoli L., Cozzi B., Fontaneto D., Lapini L., Maio N., Monaco A., Mori E., Nappi A., Podestà M.A., Sarà M., Scandura M., Russo D., Amori G., 2019. Mammals of Italy: an annotated checklist. Hystrix It. J. Mamm. 30(2): 87–106

Luque-Larena J.J., López P., Gosálbez J., 2002. Microhabitat use by the snow vole *Chionomys nivalis* in alpine environments reflects rock-dwelling preferences. Can. J. Zool. 80: 36-41.

Maiorano L., Falcucci A., Boitani L., 2006. Gap analysis of terrestrial vertebrates in Italy: priorities for conservation planning in a human dominated landscape. Biol. Conserv. 133: 455-473.

Male T.D., Bean M.J., 2005. Measuring progress in US endangered species conservation. Ecol. Lett. 8: 986-992. Doi: 10.1111/j.1461-0248.2005.00806.x

Marsh A.C., Poulton S., Harris S., 2001. The Yellow-necked Mouse *Apodemus flavicollis* in Britain: status and analysis of factors affecting distribution. Mammal Rev. 31(3-4):203-227.

Mathews F., Kubasiewicz L.M., Gurnell J., Harrower C.A., McDonald R.A., Shore R.F., 2018. A Review of the Population and Conservation Status of British Mammals. A report by the Mammal Society under contract to Natural England, Natural Resources Wales and Scottish Natural Heritage. Natural England, Peterborough. ISBN 978-1-78354-494-3.

McGuire C., 2021. National Water Vole Database and Mapping Project, Part 1: Project report for period 2009-2018. Available at: https://policycommons.net/artifacts/2422503/national-water-vole-database-and-mapping-project-part-1/3444095/ Accessed on 29.12.2022

McNab BK., 2010. Geographic and temporal correlations of mammalian size reconsidered: a resource rule. Oecol. 164:13–23. Doi: 10.1007/s00442-010-1621-5

Metcheva R., Beltcheva M., Chassovnikarova T., 2008. The snow vole as an appropriate environmental bioindicator in alpine ecosystems. Sci. Total Environ. 391:278–283. Doi: 10.1016/j.scitotenv.2007.10.007

Michaux J. R., Magnanou E., Paradis E., Nieberding C., Libois R., 2003. Mitochondrial phylogeography of the woodmouse (*Apodemus sylvaticus*) in the Western Palearctic region. Mol. Ecol. 12(3): 685-697.

Mooers A.Ø., Festa-Bianchet M., Hutchings J.A., 2007. Biases in legal listing under Canadian endangered species legislation. Conserv. Biol. 21: 572-575. Doi: 10.11111/j.1523-1739.2007.00689.x

Morehouse A.T., Boyce M.S. 2017. Troublemaking carnivores: conflicts with humans in a diverse assemblage of large carnivores. Ecol. Soc. 22(3): 4

Mori E., Mazza G., 2019. Diet of a semiaquatic invasive mammal in northern Italy: Could it be an alarming threat to the endemic water vole?. Mammal. Biol. 97: 88-94. Doi: 10.1016/j.mambio.2019.05.003

Mori E., Viviano A., Mazzotti S., Sogliani D., Bini A., Baratti M., 2022. Unveiling the genetic diversity of declining population of the harvest mouse *Micromys minutus* in Italy. Diversity 14(8):627. Doi:10.3390/d14080627

Moritz C., 1994. Defining 'evolutionarily significant units' for conservation. Trends Ecol. Evol. 9: 373-375.

Nappi A., 2002. Vertical distribution of the snow vole *Chionomys nivalis* (Martins, 1842) (Rodentia, Arvicolidae) in Italy. Hystrix 13:45–52. Doi: 10.4404/hystrix-13.1-2-4185

Oliva-Vidal, P., Martínez, J. M., Sánchez-Barbudo, I. S., Camarero, P. R., Colomer, M. À., Margalida, A., & Mateo, R. (2022). Second-generation anticoagulant rodenticides in the blood of obligate and facultative European avian scavengers. Environmental Pollution, 315, 120385.

Panzacchi M., Linnell J. D., Melis C., Odden,M., Odden J., Gorini L., Andersen R., 2010. Effect of land-use on small mammal abundance and diversity in a forest–farmland mosaic landscape in south-eastern Norway. For. Ecol. Manag. 259(8):1536-1545.

Pacifici M., Visconti P., Rondinini C., 2018. A framework for the identification of hotspots of climate change risk for mammals. Glob. Change Biol. 24:1626-1636. doi: 10.1111/gcb.13942.

607 Ranchelli E., Barfknecht R., Capizzi D., Riga F., Mazza V., Dell'Agnello F., Zaccaroni M., 2016.
608 From biology to management of Savi's pine vole (*Microtus savii*). Pest Manage. Sci. 72: 857-863.
609 doi:10.1002/ps.4212.

610 Reutter B.A., Petit E., Vogel P., 2002. *Apodemus alpicola*, using a PCR-based RFLP method. Revue
611 Suisse Zool. 109(1):9-16.

612 Reutter B. A., Helfer V., Hirzel A. H., Vogel P., 2003. Modelling habitat-suitability using museum
613 collections: an example with three sympatric *Apodemus* species from the Alps. J. Biogeogr.
614 30(4):581-590. doi: 10.1046/j.1365-2699.2003.00855.x

615 Rondinini C., Battistoni A., Teofili C., 2022. Lista Rossa IUCN dei Vertebrati Italiani. Comitato
616 Italiano IUCN e Ministero dell'Ambiente e della Sicurezza Energetica (Editions), Roma, Italy.

617 Rondinini C., Battistoni A., Peronace V., Teofili C., 2013. Lista Rossa IUCN dei Vertebrati Italiani.
618 Comitato Italiano IUCN e Ministero dell'Ambiente e della Tutela del Territorio e del Mare
619 (Editions), Roma, Italy.

620 Santini L., 1983. I Roditori italiani: di interesse agrario e forestale. Consiglio Nazionale delle
621 Ricerche editions, Roma, Italy.

622 Santini L., González-Suárez M., Russo D., Gonzalez-Voyer A., von Hardenberg A., Ancillotto L.,
623 2019. One strategy does not fit all: determinants of urban adaptation in mammals. Ecol. Lett.
624 22(2):365-376. doi: 10.1111/ele.13199

625 Sawabe K., Natuhara Y., 2016. Extensive distribution models of the harvest mouse (*Micromys*
626 *minutus*) in different landscapes. Glob. Ecol. Conserv. 8: 108-115. doi:
627 10.1016/j.gecco.2016.08.011

628 Sozio G., Mortelliti A., 2015. Empirical evaluation of the strength of interspecific competition in
629 shaping small mammal communities in fragmented landscapes. Landsc. Ecol. 31(4):775–789.

630 Strachan R., Moorhouse T., 2006. Water Vole Conservation Handbook, Second Edition. Wildlife
631 Conservation Research Unit editions, University of Oxford, Oxford, UK.

Temple H.J., Terry A., 2007. The Status and Distribution of European Mammals. Office for Official Publications of the European Communities, Luxembourg.

Vitasse Y., Ursenbacher S., Klein G., Bohnenstengel T., Chittaro Y., Delestrade A., Monnerat C., Rebetez M., Rixen C., Strebel N., Schmidt B.R., Wipf S., Wohlgemuth T., Yoccoz N.G., Lenoir J., 2021. Phenological and elevational shifts of plants, animals and fungi under climate change in the European Alps. Biol. Rev. 96:1816–1835. doi: 10.1111/brv.12727.

Vogel P., Maddalena T., Mabille A., Paquet G., 1991. Confirmation biochimique du statut specifique du mulot alpestre *Apodemus alpicola* Heinrich, 1952 (Mammalia, Rodentia). Bull. Soc. Vaudoise Sci. Nat. 80: 471-481.

Yalkovskaya L., Sibiryakov P., Borodin A., 2022. Phylogeography of the striped field mouse (*Apodemus agrarius* Pallas, 1771) in light of new data from Central part of Northern Eurasia. PloS One 17(10):e0276466. doi: 10.1371/journal.pone.0276466

Yasuda S.P., Vogel P., Tsuchiya K., Han S.H., Lin L.K., Suzuki H., 2005. Phylogeographic patterning of mtDNA in the widely distributed harvest mouse (*Micromys minutus*) suggests dramatic cycles of range contraction and expansion during the mid- to late Pleistocene. Can. J. Zool. 83(11):1411-1420. doi: 10.1139/z05-139.

Yoccoz N.G., Ims R.A., 1999. Animal Responses to Global Change in the North. Ecol. Bull. 47: 137-144

Table 1. Native species considered as not protected by the Italian law 157/1992 and their status according to the Italian red lists (from Rondinini et al. 2013, 2022).

Order	Family	Species	Common name	Red list 2013	Red list 2022	Conservation concern
Soricomorpha	Talpidae	*Talpa caeca*	Blind mole	DD	DD	Subendemic
Soricomorpha	Talpidae	*Talpa europaea*	European mole	LC	LC	
Soricomorpha	Talpidae	*Talpa romana*	Roman mole	LC	LC	Endemic
Rodentia	Cricetidae	*Arvicola amphibius*	European water vole	DD	DD	
Rodentia	Cricetidae	*Arvicola italicus*	Italian water vole	NT	NT	Endemic
Rodentia	Cricetidae	*Chionomys nivalis*	European snow vole	NT	NT	
Rodentia	Cricetidae	*Microtus arvalis*	Common vole	LC	LC	
Rodentia	Cricetidae	*Microtus brachycercus*	Calabrian pine vole	LC	LC	Endemic
Rodentia	Cricetidae	*Microtus levernedii*	Mediterranean field vole	LC	LC	
Rodentia	Cricetidae	*Microtus liechtensteini*	Liechtenstein's pine vole	LC	LC	
Rodentia	Cricetidae	*Microtus multiplex*	Alpine pine vole	LC	LC	Subendemic
Rodentia	Cricetidae	*Microtus nebrodensis*	Sicilian pine vole	NE	LC	Endemic
Rodentia	Cricetidae	*Microtus savii*	Savi's pine vole	LC	LC	Subendemic
Rodentia	Cricetidae	*Microtus subterraneus*	Common pine vole	LC	LC	
Rodentia	Cricetidae	*Clethrionomys glareolus*	Bank vole	LC	LC	
Rodentia	Muridae	*Apodemus agrarius*	Striped wood mouse	LC	LC	
Rodentia	Muridae	*Apodemus alpicola*	Alpine wood mouse	DD	DD	Restricted range
Rodentia	Muridae	*Apodemus flavicollis*	Yellow-necked wood mouse	LC	LC	

Rodentia	Muridae	*Apodemus sylvaticus*	Wood mouse	LC	LC
Rodentia	Muridae	*Micromys minutus*	Harvest mouse	LC	NT

Table 2. Legal situation of rodents and moles in some European countries

Country	**National law**	**Small mammal protection**
Germany	Bundesnaturschutzgesetz vom 29. Juli 2009 (BGBl. I S. 2542), das zuletzt durch Artikel 3 des Gesetzes vom 8. Dezember 2022 geändert worden ist. Federal Law for Nature Conservation	Moles protected; some rodents excluded
Greece	Presidential Decree (P.D.) 67 of 1981	Moles protected; some rodents excluded
Poland	Rozporządzenie Ministra Środowiska z dnia 16 grudnia 2016 r. w sprawie ochrony gatunkowej zwierząt. Ordinance of the Minister of the Environment of December 16, 2016 on the protection of animal species	Moles and some rodents partly protected; *C. glareolus* not protected. Specie of genus *Arvicola* and *Talpa* not protected in gardens, orchards and forest nurseries
Lithuania	Lietuvos Respublikos laukinės gyvūnijos įstatymas. The Republic of Lithuania Law on Wildlife	Mouse-like rodents (Muridae, Cricetidae), shrews, moles are not protected
France	Arrêté du 23 avril 2007 fixant la liste des mammifères terrestres protégés sur l'ensemble du territoire et les modalités de leur protection. Order of April 23, 2007 establishing the list of terrestrial mammals	Moles and many rodents not protected

	protected throughout the territory and the terms of their protection	
Belgium - Flanders	Besluit van de Vlaamse Regering van 15 mei 2009 met betrekking tot soortenbescherming en soortenbeheer. Decision of the Flemish Government on species protection and species management of 15 May 200	Moles and some rodents not protected
Great Britain	Wildlife and Countryside Act 1981	Moles and some rodents not protected
Czech Republic	Nature Protection Act 114/92.	All mammals are protected. Other acts allow for controlling some species (e.g. some rodents) for veterinary and agricultural reasons.
Spain	Ley 42/2007, de 13 de diciembre, del Patrimonio Natural y de la Biodiversidad. Law 42/2007, of December 13, on Natural Heritage and Biodiversity and additional regional legislation	Only few rodents and insectivores (Eulipotyphla) are protected by national law; regional laws protect other species if locally rare or endangered