Mammal Review, 47: 133–147, 2017

REVIEW
Distribution and status of the declining garden dormouse *Eliomys quercinus*

Sandro BERTOLINO *Department of Agricultural, Forest and Food Sciences, University of Turin, Largo Paolo Braccini 2, 10095 Grugliasco (TO), Italy and Department of Life Sciences and Systems Biology, University of Turin, Via Accademia Albertina 13, 10123 Torino, Italy. Email: sandro.bertolino@unito.it*

ABSTRACT

1. The garden dormouse *Eliomys quercinus*, a native European rodent species, suffered a significant contraction in its geographic range in the last few decades. The species has disappeared from large parts of central and eastern Europe and is considered extinct in some countries.
2. I reviewed the information available on the occurrence and distribution of the species in 26 countries where it was previously reported. Present and past introductions outside its native range were also summarised.
3. The garden dormouse is considered extinct in Lithuania, Finland and Slovakia, probably extinct in Belarus, and present with single populations in the Netherlands, Poland and Slovenia; in Slovakia, however, monitoring is necessary to verify recent records. The species is rare and localised in Austria, Ukraine, Romania and Croatia and is in regression in Germany, Flanders (Belgium), Czech Republic, Latvia and Estonia. In 2015, the garden dormouse occupied 49% of its 1978 geographical range and 67% of its 2008 range.
4. South-western Europe is the stronghold of the species; it is still common in large parts of Portugal, Spain, France and Italy. However, there are indications that also in these countries, the species is locally declining.
5. Present knowledge cannot explain the extensive regression of the garden dormouse's range in central and eastern Europe. Probably, it is the result of the interaction of different factors, acting locally and at a large scale, and related to specific ecological requirements of the species.
6. There is a strong need for research to determine the reasons for the dramatic population and geographic range contraction of the garden dormouse. Meanwhile, it is important to monitor this species and to identify appropriate conservation measures.

Keywords: conservation, dormice, Europe, rodent, species distribution.
Running head: Distribution and status of the garden dormouse
Submitted: 25 August 2016
Returned for revision: 5 October 2016
Revision accepted: 5 December 2016
Editor: DR

INTRODUCTION

The garden dormouse *Eliomys quercinus* is a rodent endemic to Europe, where it occurs from the western Iberian Peninsula, Italy, France and on some Mediterranean islands to central and eastern Europe and the Urals (Storch 1978, Bertolino et al. 2008). Records of this species range from sea level in the Mediterranean region up to over 2000 m a.s.l. (elevation, above sea level) in the Alps. It colonises different habitats from deciduous to coniferous and mixed forests, and from plains to hilly and cultivated lands (Storch 1978, Bertolino et al. 2008).

The systematics of the genus *Eliomys* has been subject to many revisions. A long list of names was reduced to two by Ellerman and Morrison-Scott (1966): *Eliomys quercinus* in Europe and North Africa and *Eliomys melanurus* in the Middle East. After the revision by Storch (1978) for the European populations and by Niethammer (1959) and Kahmann and Thomas (1981) for the North African populations, only one species was recognised, *Eliomys quercinus*, composed of three groups of subspecies with differences in the colour of the tail (Filippucci et al. 1988b). The *quercinus* group comprised subspecies present in most of the western European part of the species' range, in the Balearic Islands, Russia, Morocco and Algeria. The *lusitanicus* group included subspecies from the southwestern part of the Iberian Peninsula, the island of Formentera, the Italian mainland and Sicily, Sardinia, Corsica, the Aeolian Islands and Dalmatia (Croatia). The *melanurus* group included subspecies native to North Africa and the Middle East. Subsequently, Filippucci and co-authors, using karyotype and allozyme diversity, indicated the existence of two distinct evolutionary lineages, corresponding to the species *Eliomys quercinus* in Europe and *Eliomys melanurus* in North Africa and the Middle East (Filippucci et al. 1988a, b, Filippucci & Capanna 1996); a similar result was obtained by Simson et al. (1994) by analysing phalli and bacula. Kryštufek and Kraft (1997) conducted a comprehensive craniometric study, finding no correspondence between morphotypes (tail colour) and skull morphotypes. They also recognised two distinct species, but included European and North African populations east of Tripolitania in *Eliomys quercinus*, restricting *Eliomys melanurus* to the Asiatic range of the genus and in North Africa east from Cyrenaica. Wilson and Reeder (2005) reviewing morphological, kariological and allozymic data, considered the populations in western North Africa (Marocco, Algeria, Tunisia, East Lybia) to form a distinct species called *Eliomys munbyanus*. The recognition of the taxonomic validity of *Eliomys munbyanus* was previously suggested by Delibes et al. (1980) and by Filippucci and Capanna (1996). According to Wilson and Reeder (2005), the genus *Eliomys* is now divided into three species: *Eliomys quercinus* in Europe, *Eliomys munbyanus* in western North Africa and *Eliomys melanurus* in eastern North Africa, the Middle East and South Turkey.

Perez et al. (2012) identified four evolutionarily significant units within the range of *Eliomys quercinus*, corresponding to mitochondrial lineages: Iberian (2N = 48), Italian (2N = 48, 50), western European (2N = 48, 49, 50) and Alpine (2N = 52, 54) clades.

Distribution maps of the garden dormouse are reported by Storch (1978), in the European Mammal Atlas (Filippucci 1999) and on the International Union for Conservation of Nature (IUCN) Red List web site (Bertolino et al. 2008). The species is listed in Appendix III of the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats, 1979). It is specifically excluded from the Habitats Directive (Council Directive 92/43/EEC), which in Annex IV lists all Gliridae except the *Glis glis* and *Eliomys quercinus*. The garden dormouse is considered Near Threatened by the IUCN (Bertolino et al. 2008) because it is suffering significant ongoing decline and may have disappeared from large part of its former range during the last 30 years. The species is still considered common in western and southern Europe, but seems to be rare in central Europe, where it has a patchy distribution with local extinctions (Bertolino et al. 2008).

Considering that in recent times the garden dormouse has contracted its range and declined more than almost any other rodent in Europe (Bertolino et al. 2008), it is important to evaluate the present status of the species. For this reason, I reviewed the information available for every country where the species was previously reported. In this paper I summarise current knowledge about the distribution and the population trends of the garden dormouse in order to assess its status and propose conservation actions.

METHODS

I compiled a list of countries in which the garden dormouse was reported, starting from published studies in which the distribution and status of dormice was reviewed (e.g. Storch 1978, Filippucci 1999, Bertolino et al. 2008). Subsequently, I searched through the literature and in websites in order

to collect information on the presence and status of the species in each country. Important for this search were the Proceedings and Abstract books of the International Conferences on Dormice that have been organised in Europe since 1990 every three years. Articles on dormice in general and *Eliomys* in particular were searched using electronic databases, including Zoological Records, Web of Science, and Scopus. Internet searches on the Worldwide Web were performed using different search engines. During the search, terms such as '*Eliomys'*, 'dormice', 'mammals list' and 'red list' were matched with the names of single countries. Additional information was acquired by using reference tracking from the books and articles collected. Several experts were contacted directly and provided new information and additional bibliographic resources.

The map produced for this review was compared with those previously published by Bertolino et al. (2008) and Storch (1978). The map given by Bertolino et al. (2008) shows the entire range of the species, while Storch (1978) included only parts of the Russian range of the species. Therefore, the comparison with the map of Storch (1978) was done considering only the area covered by these authors. The map given by Filippucci (1999) was not used because it was even more restricted in its range than that of Storch (1978), not including Russia, Belarus and Ukraine.

RESULTS

The status of the garden dormouse in each country is presented below, moving approximately from west to east (see also Table 1). The geographic range in the year 2015 is shown in Fig. 1. An updated map was not available for Russia; therefore, for this country, I simply reported the garden dormouse's range from Bertolino et al. 2008. In 2015, the garden dormouse occupied 49% of its 1978 geographical range and 67% of its 2008 range. Of the 26 countries considered, the garden dormouse was not found or of unknown status in four, is extinct or probably extinct in four, and present only in single small populations in three, rare or declining in 10, and still common in five.

Portugal

The garden dormouse is reported for the entire continental territory of Portugal, but there are no recent data to confirm its presence in a wide area in the centre and south of the country, where a decline of the species is considered possible (Cabral et al. 2005). In other parts of the country, populations may be abundant, but scattered (Santos-Reis & Mathias 1996). The species is considered Data Deficient in the 'Livro Vermelho dos Vertebrados de Portugal' (Cabral et al. 2005).

Spain

The species is widely distributed in mainland Spain and is also present in the Balearic Islands, except Ibiza (Moreno 2002). In the south, where it was formerly abundant, it is now considered rare (Ruiz & Roman 1999, Moreno 2002, Santoro et al. 2016). Garden dormice were recorded in different habitats, including rocky areas, pine woodlands, broadleaf forests and orchards, from sea level up to 1500 m a.s.l. in the Pyrenees (Moreno 2005; Gil-Delgado et al. 2010). Four subspecies were identified in Spain: *Eliomys quercinus lusitanicus*, present in the south-western part of the peninsula, *Eliomys quercinus quercinus*, in the other parts of the peninsula, *Eliomys quercinus gymnesicus* , on the islands of Mallorca and Menorca, and *Eliomys quercinus ophiusae*, on the island of Formentera (Moreno 2005). In the 'Libro Rojo de los Vertebrados de Espana', the species is considered of Least Concern, but the subspecies *Eliomys quercinus ophiusae* is considered rare (Moreno 2005).

France

The garden dormouse is widely distributed in mainland France, except in Bretagne, where it is rare, probably due to the absence of suitable habitats; it is also present on the island of Corsica (Le Louarn & Quéré 2003). Records are from the plain up to 2500 m a.s.l. in the Alps and Pyrenees. In the Alps, habitats favourable to the species are characterised by the presence of rocks and stones

and a reduced and fragmented herbaceous cover under a sparse tree canopy (Le Louarn & Spitz 1974). The species is considered of Least Concern in the national Red List (Anonymous 2009).

Italy

The distribution of dormice in Italy was reviewed by Amori et al. (1994) and Capizzi and Filippuci (2008), who considered the garden dormouse to be widely distributed in the country. The species inhabits mainly coniferous and mixed forests in the Alps up to 2200 m a.s.l. and deciduous and coniferous forests in the Apennines up to 1900 m a.s.l. On the islands and in some central and southern continental areas, it also occurs in Mediterranean forests and cultivated lands. The species is also present in habitats with few trees and shrubs, but with many rocks and stones or dry-stone-walls (Capizzi & Filippuci 2008). Populations on the islands (Sardinia, Sicily, Lipari) seem to be decreasing (Amori 1993), and the proposed subspecies *Eliomys quercinus sardus* (Sardinia), *Eliomys quercinus dichrurus* (Sicily) and *Eliomys quercinus liparensis* (Lipari island) have become rare (Sarà 2008). According to Sarà (2008), the garden dormouse is affected by fires that change its habitat and suffers from competition with the brown rat *Rattus rattus*. The species is considered Near Threatened in the national Red List (Bertolino et al. 2015) and is of conservation concern (Bertolino et al. 2014).

Former Yugoslavia

The status of the garden dormouse in the former Yugoslavia (Slovenia, Croatia and Bosnia and Herzegovina; there are no records from the other countries) was reviewed by Petrov (1992), who described its range as restricted to the north and central parts of the Adriatic coast, from the Kvarner Gulf to the Neretva River, and some Adriatic islands. This range was isolated from the Italian, Alpine and Carpathian populations of the species.

Slovenia

The garden dormouse has been reported several times in Slovenia, and the species was included in the faunal lists of the country (Kryštufek 2003). However, all these records were rejected by Kryštufek (1991, 2003) due to erroneous identification. The first and only documented record of the species in Slovenia comes from Dane near Stari trg pri Ložu (580 m a.s.l.) on the north-eastern slopes of the Dinaric Alps, and has the characteristics of the Dalmatian subspecies *Eliomys quercinus dalmaticus* (Kryštufek 2003).

Croatia

The garden dormouse is distributed along the Adriatic coast of Croatia and on the islands of Krk, Pag, Brač, Hvar, Korčula and Lastovo in the Dalmatian form *Eliomys quercinus dalmaticus* (Petrov 1992, Tvrtković et al. 1994, Kryštufek 2003, Kryštufek & Kletečki 2007). The species is probably threatened by *Rattus rattus* on islands; its presence on Lastovo and Korčula was not confirmed for 50 years after the first findings (Nikola Tvrtković, pers. com.). According to Tvrtković et al. (1994), specimens from the southern slopes of Medvednica Mountain and old observations from the southern slopes of Satnoborsko indicate a wider distribution of the garden dormouse in the recent past. However, these records may be incorrect identifications, and thus the species is probably restricted to Mediterranean habitats on the littoral slopes of the Dinaric Alps between 100 and 980 m a.s.l. (Tvrtković et al. 1994, Kryštufek 2003). Here, it has been reported in five of the 11 forest types populated by dormice species (Tvrtković et al. 1994). The garden dormouse is considered Near Threatened in the Red Data Book of the Mammals of Croatia (Tvrtković et al. 2006).

Bosnia and Herzegovina

According to the map in Petrov (1992), in the former Yugoslavia, the garden dormouse reached the Neretva River valley, part of present Bosnia and Herzegovina. Tvrtković et al. (1994) listed two records east of the Neretva River (Metkovic in Croatia and on the Prenj Mountain in Bosnia and

Herzegovina), indicating that the south-eastern boundary of the species' distribution is not restricted by the river. Another map, proposed by Glasnović et al. (2009) in the report for the Dinaric Arc Ecoregion Project, included the garden dormouse in the checklist of mammals in Bosnia and Herzegovina; however, further information on the species' status is not available (Kotrošan et al. 2005).

Austria

The garden dormouse has been present in Austria since the Pleistocene, and there are five fossils from the Holocene: one from the western part of the country in the Vorarlberg and four from the eastern part in Lower Austria and Styria (Spitzenberger 2001). This range has been reduced in the last four to five centuries, and currently, the eastern limit is in the Wipptal. At present, all records are from the western part of the Alps in Vorarlberg and Tirol (Spitzenberger 2001). The species is mainly reported in the sub-mountainous zone, between 800 and 1600 m a.s.l.; only eight records are from higher elevations (1700-2100 m). The species is considered of Least Concern in the national Red List (Zulka 2005).

Switzerland

The mammal atlas for Switzerland was published in 1995 (Longchamp 1995), and an update is available online (https://lepus.unine.ch/carto/index.php). In Switzerland, the garden dormouse is present in the montane and subalpine belts of the mountains, while it is absent from areas at lower elevations (Longchamp 1995). The distribution of the species after 2000 overlaps extensively with the one before that year (both mapped in the online atlas update), although the species no longer seems to be present in the areas around the city of Basel and south of Lake Zurich, where it was reported before 2000. The garden dormouse is not considered at risk in the national Red List (Duelli 1994, Red List in revision for mammals).

Germany

In Germany, the garden dormouse is declining and it is now considered common only west of the River Rhine, while on the eastern side, it is rare and localised. Meinig and Büchner (2012) compared information collected from 1990 to 2012 with previous distributional information. This showed that a range contraction had taken place, that the species had become locally extinct in some parts of its former range, and that its range is presently quite fragmented (Fig. 1, Meinig & Büchner 2012). The species seems more or less stable in Lower Saxony, Hesse, the lowlands of Rhineland-Palatinate and Baden-Württemberg; it is declining, or locally extinct, in North-Rhine-Westphalia around the city of Bonn and Thuringia, and has an uncertain status in Saarland and Bavaria. In Saxony, the garden dormouse was common until approximately 1900, but thereafter the species was only known from the mountains in the south (Zimmerman 1921). In the 1920s, it went extinct in the south-eastern mountains of Saxony, while the western population vanished between 1980 and 1990 (Meinig & Büchner 2012). Now, even with intensive searches, the species can no longer be found there. The garden dormouse is not present in the north and north-east of Germany. Populations of the western lowlands are typically found in gardens and orchards, while in the eastern parts, the animals are dispersed in spruce-dominated mountainous forests, often in places with boulder fields and areas with bare soil (Meinig et al. 2009, Meinig & Büchner 2012). In the German Red List, the garden dormouse is classified as Assumed to be Endangered because of a lack of data (Meinig et al. 2009).

Luxembourg

The garden dormouse was reported to be common in Luxembourg in the past, but localities of its presence were not reported (De La Fontaine 1868, Ferrant 1931). While conducting a literature survey on mammals in Luxembourg, Engel (1989/1990, unpublished) found only four reports for the species, all from owl pellet studies conducted between the 1930 and 1960. During a first survey

in 1993 (by the National Museum of Natural History, unpublished) and a new survey in 2009 (Jörg Schlichter, pers. com.), the species was found in two centres of occurrence: the Moselle Valley in the east, and in the northeast around the city of Diekirch (Sûre Valley). Most of the records were from the Moselle Valley, an area rich in orchards and vineyards, as well as old villages with barns and sheds, providing the animals with nesting sites. There is no general Red List for mammals in Luxembourg.

Belgium

The garden dormouse is the most widespread dormouse in Belgium. The species occurs mainly in the southern part of the country, while it seems to be found sporadically in the north and in the Ardennes. The distribution in Flanders is restricted to loamy soils and the west coast, probably due to the availability of food there, particularly snails and crickets, which are lacking in other areas (Cortens 2008). The species was reported in 238 out of 645 5-km-squares covering the region. However, breaking these records down into three time-periods shows that 156 squares were inhabited by the species before 1987, 147 squares from 1987-2002, and only 121 squares from 2003-2008, indicating a slow rarefaction (Cortens & Verbeylen 2009). The garden dormouse is considered to be Endangered in Flanders (Maes et al. 2014) and of Least Concern in Wallonie (Observatoire de la Faune, de la Flore et des Habitats, http://biodiversite.wallonie.be/fr/mammiferes.html?IDC=321).

The Netherlands

In the Netherlands today, the garden dormouse is present only in the southwest of the province of Limburg, in one local population of about 70 individuals (Kuipers et al. 2012). The species is considered the rarest mammal in the Netherlands and is classified as Critically Endangered in the national Red List (Anonymous 2007, Thissen et al. 2009). The basis of this evaluation is an area of occupancy of less than 10 km^2, a small population size of 40-80 reproducing individuals, and a decline of at least 30% over five years in terms of population size and of 59% in terms of geographic range size over a decade. Compared to the distribution in 1950, in 2005, the range contraction was 83% and the population size decline was 97% (Anonymous 2007).

Finland

The garden dormouse was reported to occur in Finland in Heinola and Jaala in the southern part of the country. However, there are no records from this area after the 1970s (Heikki Hentonen, pers. com.). Four animals were captured in 1991 at Teuva, west of the previous population, but the presence of the species was not confirmed despite further trapping efforts; there are no old records in that area (Heikki Hentonen, pers. com.). The species is considered Regionally Extinct in the Finnish Red List (Rassi et al. 2010).

Former Soviet Union

The eastern part of the garden dormouse's range encompassed parts of the former Soviet Union (Lithuania, Latvia, Estonia, Russia, Belarus, Ukraine and Moldova; there are no records from the other countries), where three separate areas were inhabited by the species. The first covered the Baltic States (Lithuania, Latvia, Estonia), Leningrad, Pskov, Novgorod, Yaroslavl, Kursk and the Bryansk province as well as some regions of Belarus (Mogilev region), Ukraine (Kiev region) and Moldova (forest subcarpathia and central Moldova). The other two were in the South Urals and the Volga region, where the species was reported in the Gorky Oblast, Tatarstanom, Kostroma province and Zhigulevskom (The Biodiversity Conservation. Status Survey and Action Plan for Rodents of the former USSR: http://www.biodiversity.ru/eng/programs/rodents/index.html).

Lithuania
The garden dormouse was recorded only in southern Lithuania, in the Varena district, where four to six juveniles were found in nest boxes from 1957-1959 (Juškaitis 1994). The dormice were observed in dry Scotch pine *Pinus sylvestris* forest with juniper *Juniperus communis* and a ground cover of moss and lichens. During new surveys in the same locality, the species was not found again, and the population must be considered extinct (Juškaitis 2003). The status of this species in the Red Data Book of Lithuania changed in 2000 from Category 4 (indeterminate) to Category 0 (extinct or probably extinct; Juškaitis 2003).

Latvia
The garden dormouse was considered common in Latvia until around 1900, and some authors indicate that this species was still frequently found in the Cesis district in the 1950s (Pilāts 1994). In recent decades, the species seems to have practically disappeared (see Fig. 3 in Pilāts 1994) and it is now considered rare in the country (Timm et al. 1998). The garden dormouse is listed under Category 3 (rare) in the Red Data Book of Latvia (2000, http://www.latvijasdaba.lv/ziditaji/eliomys-quercinus-l). Records of garden dormice are from deciduous and pine forests as well as orchards. The causes of the decline are unclear. In Latvia, dormice have never been directly threatened by harvesting. Forest management could have influenced population survival through the removal of old hollow trees and understory shrubs, but intensive forest harvest has not taken place during the last 50 years. The total area of forests increased from 25% in 1935 to 41% of Latvia's land area in 1991 (Pilāts 1994). However, the mosaic distribution of dormice species in Latvia probably makes it impossible for the garden dormouse to recolonise disjointed areas.

Estonia
In Estonia, the garden dormouse was considered quite common, but now few localities where it is present are known, and the species is considered very rare (Pilāts 1994, Timm et al. 1998). The 1998 national Red List category for the species was Rare (Anonymous 1998), which is similar to the Near Threatened IUCN category. The Red Data Book of Estonia (Anonymous 2008) lists the species as Data Deficient.

Russia
The northern border of the garden dormouse's geographic range was from southern Finland, via south and central Karelia, Leningrad, Vologda, Kostroma, Gorkij, and Kirov regions, as far as to the South Ural Mountains (Airapetjanc 1967). Around Leningrad, isolated and small populations were mainly found in the western and central parts of the region along the Luga and Volkhov Rivers and their tributaries, on the southern coast of the Gulf of Finland and on Bolshoy Tyuters Island (Airapetjanc & Fokin 2002). In the Nizhniy Norgozod region, the species is rare on the right bank of the Vola River, while it seems more common on the other bank (Pavlinov et al. 2012; Nikolai Formozov, pers. com.). In the Leningrad region, the garden dormouse used to be caught regularly in most forest habitats (in mixed forests, middle-aged pine forests, coniferous-mixed forests and in coppices). It has been suggested that until the glaciations, the garden dormouse was closely connected with broad-leaved forests, which reached the Kola Peninsula in the Eocene and Pleistocene periods. During the glacial period, the species survived in southern European refugia from where it spread towards the north in warmer periods (Airapetjantc 1967). The garden dormouse is considered Vulnerable in the Red Data Book of the Leningrad Region (Airapetjanc & Fokin 2002).

Belarus
The garden dormouse is listed under Category 3 (Vulnerable) in Kachanovskii (2015). However, the species was reported from seven localities from 1920-1962 and only one afterwards (Brest

district in 1996). The absence of records afterwards suggests that it has disappeared from the country.

Ukraine
There are no data in the literature concerning the distribution of the garden dormouse in Ukraine confirmed by collection of material before the 1960s. Four localities were discovered from 1965-1986 (Girenko & Litvinenko 1971, Bezrodnij 1991), and some other records in 1993 were from western Ukraine (Andriy-Taras Bashta pers. com.). This confirms that in the former Soviet Union, the southern border of the garden dormouse's geographic range did not pass through Belarus (Likhachev 1972), but through Ukraine. Old records were from the Cherkasy, Kiev, Rovne and Transcarpathian regions. However, the range was strongly restricted to the east and south, and the species probably remained only in Volyn and Central Polissa (Zagorodniuk 2009). According to the Red Data Book of Ukraine, the species is considered to be Vanishing, a protection category that corresponds to the Critically Endangered category of the IUCN (Zagorodniuk 2009).

Moldova
The garden dormouse is not included on the list of mammal species that presently inhabit Moldova. According to Anatol Savin (pers. com.) in the 1950s or 1960s, several individuals were recorded in the Codri Forest, about 50 km from Chisinau City. However, in the last 30-40 years, the species has not been recorded.

Poland
The garden dormouse is only known from southern Poland, where it was present in only one or a few small and isolated populations. Seven localities were listed in the Polish Red Data Book of Animals (Pucek 2001), but only two, in Babia Góra and the Pieniny Mountains, have been confirmed since the Second World War, and only Babia Góra since 1961 (Jurczyszyn & Wolk 1998). According to the new ongoing Mammal Atlas of Poland (Atlas Ssaków Polski: http://www.iop.krakow.pl/ssaki), the species is still recorded only from one place in Babia Góra. The garden dormouse is considered Critically Endangered in Poland (Pucek 2001).

Former Czechoslovakia
Anděra (1986) reported on the distribution of the garden dormouse in the former Czechoslovakia (Czech Republic and Slovakia), identifying two main regions of presence: the mountainous and highland areas of Western Bohemia, and the karstic areas in south-eastern Slovakia, including some parts of the Carpathian Mountains. The species was reported from 83 localities in 28 regional areas, but only 18 localities in seven regional areas were confirmed by records from 1950-1990, showing an evident contraction of the species' range. Preferred habitats were stony and rocky ecotone stands, but the species was also recorded from mixed and coniferous forests. The elevational range was 140-1028 m a.s.l.; the maximum occurrence was at 200-800 m a.s.l.

Czech Republic
Andera (1994) reported the species from a few mountains and highlands of the Western Bohemia borderland, and an isolated population in Central Bohemia. Beneš et al. (2002) reviewed historical records of the species in Moravia and concluded that there was evidence from only two localities: Heřmanice and Drahany. Until 1950, the garden dormouse had been recorded occasionally in 28 squares of the present Czech Republic national grid system. A similar number of squares (27) was found to be occupied by the species in 1950-1990 during more intensive field searches. Since 1990, the species was confirmed in only 11 squares (suggesting a range contraction of -61%) in three regions in the Czech-German borderland (Mikeš & Sedláček 2008). During a recent survey, the garden dormouse was trapped only in the Bohemian forests, especially in the ecotone of open screes

and surrounding coniferous forests (Mikeš & Sedláček 2008). The species is considered Endangered in the Red List of Threatened Species of the Czech Republic (Plesník et al. 2003).

Slovakia

Anděra (1994) considered the garden dormouse to be relatively common in the Slovakian karstic area and in some parts of the Carpathian Mountains; however, most of the records were from owl pellets that were difficult to date. The last garden dormice were caught in Slovakia in the 1960s (Košel 1971), and the species was thus considered Extinct in the last Red List (Žiak & Urban 2001). Some skeletal remains are, however, sporadically found in owl pellets; the most recent ones were found in 2004 in fresh pellets of tawny owls *Strix aluco* roosting in a cave in the Muranska Planina Mountains (Obuch 2004). Considering these records, a specialised trapping survey in different areas of the country has been suggested, to verify whether viable populations are still present in Slovakia (Ambros 2008).

Romania

The distribution of the garden dormouse in Romania is not well known. It was reported in Tara Barsei in the middle of the country, on Retezat Mountain (southern Carpathian Mountains) and in the Cobia Forest near Craiova (Botnariuc & Tatole 2005). In these hilly and mountainous regions, the species was found mainly in deciduous and mixed forests. However, all known records were reported in papers published before the 1980s, except for the record from the Cobia Forest (Popescu & Murariu 2001), which is more recent (D. T. Murariu, pers. com. 2006). The garden dormouse is considered Vulnerable in the national Red List (Murariu in Botnariuc & Tatole 2005).

Bulgaria

The garden dormouse was reported to be present in Bulgaria by various authors (Kovachev 1925, Heinrich 1936, Atanassov & Peschev 1963). However, to date there is no reliable evidence to confirm its presence in the country (Peshev et al. 2004; V. Popov pers. com.). According to Kovachev (1925), the species was found near Belovo (Pazardzhik district, South Bulgaria); however, the specimen that was photographed was subsequently lost (Peshev et al. 2004). The specimen in the National Museum of Natural History in Sofia is from Thuringia (Germany). The record from the vicinity of Nessebar (southern part of the Bulgarian Black Sea coast, Heinrich 1936) is based on an incorrect determination (Angermann 1966).

Introductions

Remains of the garden dormouse were found in southern England in archaeological deposits of Roman date; the species was probably imported from the French coast as a food source (O'Connor 1986). Garden dormouse introductions continue today. A total of 11 animals have been discovered in England on four occasions at Dover (1990), Carshalton Beeches (1991) and London (1992 and on another undated occasion; Harris & Yalden 2008); however, there is no evidence that these animals have become established. In Denmark, a few animals that probably arrived with a cargo were the origin of a population that is now settled in South Jutland (Jensen & Erritzoe 2001). Meinig and Büchner (2012) reported cases of animals escaped from captivity in Germany, where the species is bred in captivity, and accidental transports by vehicles.

Mediterranean islands

The garden dormouse is present on the three main Mediterranean islands: Corsica, Sardinia and Sicily. On the first two, it was introduced by humans (Vigne 1992); a human influence cannot be excluded for Sicily (Ientile & Massa 2008).

On the Balearic Islands, the garden dormouse is currently present in Mallorca, Menorca and Formentera, where it was introduced in 2300–2200 B.C. (Traveset et al. 2009). According to fossil

records, the species was also introduced onto Ibiza and Cabrera, but it disappeared later, probably due to the introduction of predators (Traveset et al. 2009).

In Italy, the garden dormouse has been reported on the islands of Lipari and Asinara, probably as a result of introductions for food in Roman times (Masseti 2005, Angelici et al. 2009); the last record from Lipari dates back to 1992, despite subsequent research (Sara 2008).

On the Adriatic Islands, the garden dormouse was reported at Krk, Hvar, Brač, Pag, Korčula and Lastovo (Kryštufek & Kletečki 2007), probably as a result of natural colonisation (Nikola Tvrtković pers. com.). The presence of the species has not been confirmed recently on Korčula and Lastovo (Nikola Tvrtković pers. com.).

DISCUSSION

According to the results of this review, the garden dormouse is still common and widely distributed only in south-western Europe, mainly in Portugal, Spain, France and Italy, while it has disappeared or is declining in central and eastern Europe. The species is considered extinct in Lithuania, Finland and Slovakia, though in Slovakia, monitoring is necessary to verify recent records. It is probably extinct in Belarus, since there have been no records in recent decades. In the Netherlands, the garden dormouse is present as only a single small population, while in each of Poland and Slovenia only one record is presently known; therefore, the risk of extinction in these countries is high. The species is rare and localised in Austria, Ukraine, Romania and Croatia and in regression in Germany, Flanders (Belgium), Czech Republic, Latvia and Estonia. There is also evidence of rarefaction in some areas in Belgium, Italy and Spain. The species is considered to be Critically Endangered in the Netherlands, Poland and Ukraine, Endangered in the Czech Republic and Flanders (Belgium), Vulnerable in Belarus, Romania and the Leningrad region and Near Threatened in Italy and Croatia (see Table 1).

Overall, in recent decades, the garden dormouse has been lost from most of its range in central and eastern Europe; populations have extensively regressed and are now patchy and isolated. The species is still suffering significant ongoing decline in this part of Europe, though it maintains a stronghold in the south-west. The species must therefore be considered to be one of the European mammals that suffered the largest decline in recent times.

Anděra (1986) considered the present occurrence of the garden dormouse in central Europe to be a relict of a former extensive geographic range. The first fossil records are from the medium Pleistocene. Fossils from the interglacial periods are rarely found outside the glacial refugia in the Mediterranean area and the south of France. Fossil findings confirm the presence of the species in central Europe and in the area east of the Baltic Sea during the Holocene. Therefore, the species must be considered a western Mediterranean element in origin, which penetrated central and eastern Europe during the Holocene. It has invaded the eastern Alps together with an open xerophytic pre-boreal vegetation (Spitzenberger 1983), reached the Czech lands during the Neolithic period (Horaček 1986) and the western Carpathian Mountains only during the sub-Atlantic period (Obuch & Darola 1980, cited in Anděra 1986). Overall, it seems that the species is mainly regressing from its secondarily colonised range.

Dormice are naturally rare and present with populations at low density (Bright & Morris 1996). In recent times, natural scarcity has been exacerbated by anthropogenic factors, and some species are now regarded as rare or endangered, requiring conservation-related research and active habitat management to assist their survival. The hazel dormouse *Muscardinus avellanarius* in England is an example: the causes of its rarity in recent times have been widely investigated, and conservation measures have been proposed. On the other hand, the garden dormouse is poorly studied, and many questions regarding its ecology and adaptive behaviour are still awaiting an answer.

Rarefaction in central Europe has been explained by a present lack of suitable habitats; extensive woods have replaced open areas with shrubby vegetation (Anděra 1994). If this explanation is correct, a similar decline of the species would be predicted to occur in the Alps, where reduced livestock grazing in recent decades is leading to the expansion of woodlands; here, however, the species seems still to be in a favourable condition (Longchamp 1995, Bertolino et al. 2001, Capizzi & Filippucci 2008). Santoro et al. (2016) related the disappearance of the garden dormouse from some areas in southern Spain to local climate warming. However, these areas represent the southern limit of the geographic range of a species that is better adapted to colder climates. It is therefore an extreme situation, that can hardly be generalised to other areas in central and eastern Europe.

The garden dormouse is a glirid that spends most of its time on the ground (Vaterlaus-Schlegel 1997, Bertolino et al. 2003). It occurs in many habitats, including forested areas from Mediterranean woodlands to temperate deciduous and alpine coniferous forests, mountain scree, semi-desert areas, sand dunes and also more anthropogenic habitats, such as farms and orchards (Bertolino et al. 2008, Gil-Delgado et al. 2010), indicating its adaptability to different conditions. A preference for stony and rocky environments, often with a well-developed shrub layer and a reduced herb cover, has been recognised in many cases (Le Louarn & Spitz 1974, Petrov 1992, Moreno 2002, Bertolino 2007). Rocks and stones may provide protection from predators and are used as refuges, they also reduce thermal stress (Bertolino & Cordero di Montezemolo 2007). In the Bohemian forests, for example, the remaining populations of garden dormouse are often found in open screes surrounding coniferous forests (Mikeš & Sedláček 2008).

With our present knowledge, it is not possible to explain the extensive contraction of the garden dormouse's range in central and eastern Europe. It might be a result of interactions between various factors that act at a local level or at a wider range, and is probably related to the specific ecological requirements of the species. Changes at the landscape level, especially in vegetation cover and composition, due to changes in climate and human pressure, including the reduction of landscape management in some areas, may be responsible for the regression of the species from its secondarily colonised range. Interactions with the edible dormouse *Glis glis* and the forest dormouse *Dryomys nitedula* may have contributed to this regression. The patchy distribution of the garden dormouse in its contact zone with the forest dormouse, and the disappearance of the former in areas inhabited by the latter species, suggest the penetration of the forest dormouse in the previous range of the garden dormouse (Kryštufek & Vohralik 1994). This, however, could be due to colonisation by the forest dormouse of the areas vacated by the garden dormouse, and may not be the result of competition.

My review of the literature showed that recent rarefaction and extinctions of the garden dormouse have resulted in a halving of its range since 1978, and in a reduction by one-third since 2008. I have to acknowledge that the map provided by Storch (1978) seems to be approximated in the eastern part of the range, and probably the species' range was less continuous than reported. Furthermore, in some cases, borders in both previous maps passed through areas where the species was in fact not reported locally or where it had already vanished by the year of map compilation. However, this approximation is inherent to range maps based on the extent of occurrence of a species at a continental scale, and should not influence the general picture of the species' distribution. In fact, the map presented here also lacks updated information for some countries (e.g. Russia) and probably overestimates the real distribution of the species.

During the last IUCN assessment, the garden dormouse was considered Near Threatened because it was suffering a significant ongoing decline, the cause of which was not understood, though the range reduction over the last ten years was considered to be less than 30% (the threshold for Vulnerable under IUCN Criterion A). I have documented a further range contraction decline in the occurrence of the species. According to the IUCN Red List criteria (Anonymous 2012), re-evaluation of taxa against the criteria should be carried out at appropriate intervals; this is especially important for taxa listed as Near Threatened and Data Deficient. Therefore, I propose a change to

the status of the garden dormouse to Vulnerable in the IUCN Red List, according to criteria A2c: "an observed, estimated, inferred or suspected population size reduction of ≥30% over the last ten years, where the reduction or its causes may not have ceased or may not be understood, based on a decline in area of occupancy, extent of occurrence and/or quality of habitat". It should be underlined that a range contraction is still ongoing, the causes are not understood, and there are indications that even the western populations, considered the stronghold of the species, are at risk in some areas. To this end, the reported indications of local reductions in Spain (Ruiz and Roman, 1999, Moreno 2002) and Italy (Amori 1993, Sarà 2008), and the lack of data from Portugal (Cabral et al. 2005), promote the garden dormouse as a priority species for national monitoring projects in these countries (Bertolino et al. 2014).

The inclusion of the hazel dormouse and the forest dormice in Habitats Directive 92/43/EEC has resulted in the requirement for regular monitoring of the species and the implementation of conservation measures when needed. The exclusion of the garden dormouse from the protection granted to most dormice (all glirids, except *Glis glis* and *Eliomys quercinus*, are listed in Annex IV) seems inexplicable. Considering the sharp decline in numbers of the garden dormouse in recent decades and the absence of any significant economic damage attributable to this species, its listing in the Habitats Directive, if a review is made, seems particularly necessary and justified.

ACKNOWLEDGEMENTS

Many people provided information on present and old records of the garden dormouse as well as grey literature, and translated papers from other languages into English. I am particularly grateful to Pat Morris (England), Vadim Sidorovich (Belarus), Boris Kryštufek (the former Yugoslavia), Nikola Tvrtković (Croatia), Goedele Verbeylen (Belgium), Dumitru Murariu (Romania), Sven Büchner and Holger Meinig (Germany), Heikki Hentonen, Marja Pylvänäinen and Ulla-Maija Liukko (Finland), Rimvydas Juškaitis (Lithuania and the former Soviet Union), Nikolai Formozov (Russia), Hanna Zaytseva and Andriy-Taras Bashta (Ukraine), Vasil Popov (Bulgaria), Jörg Schlichter (Luxembourg), Václav Mikeš (Czeck Republic), Anatol Savin (Moldova). Links to websites were all checked on 10/01/2017.

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Figure 1. Distribution of the garden dormouse *Eliomys quercinus* in Europe, according to the present study (2015; dark grey), Storch (1978; crosshatching and dark grey), and Bertolino et al. (2008; light and dark grey).

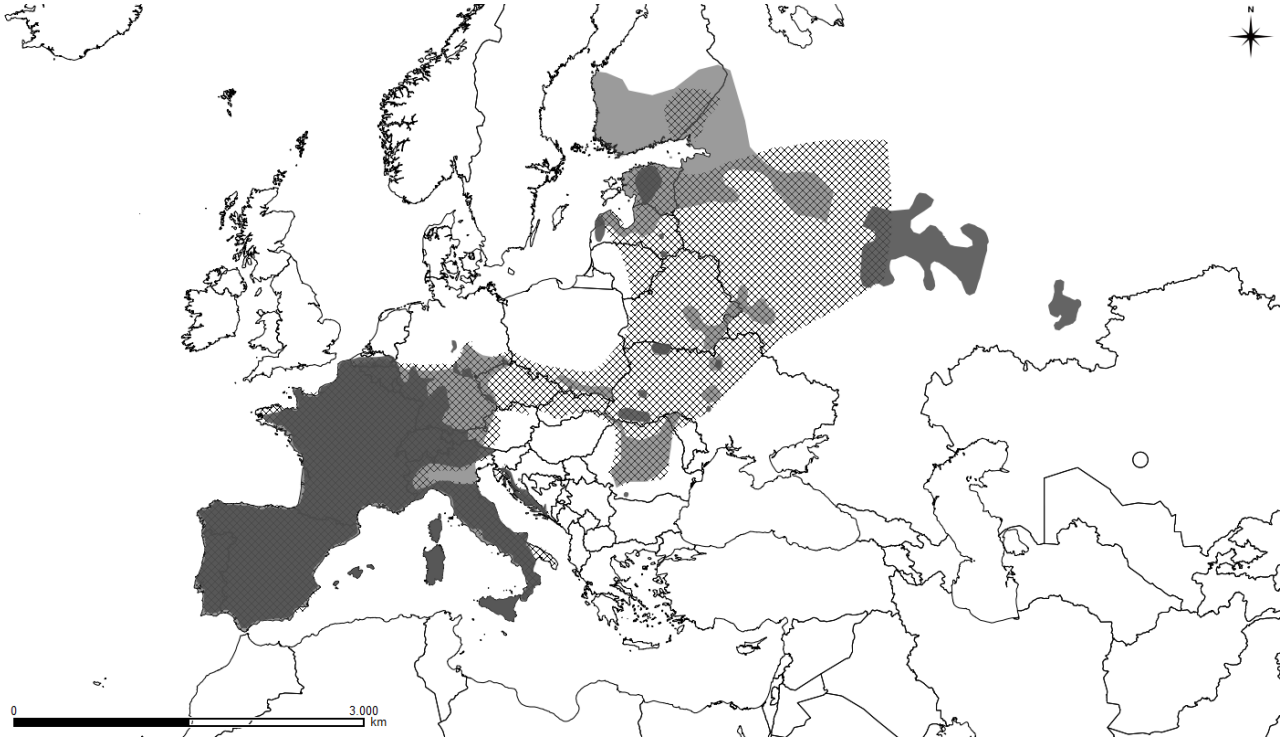

Table 1. Status of the garden dormouse in each of the 26 European countries included in this review.

Country	Status	Red list category	Comment	Reference
Portugal	Common	Data Deficient	Abundant but scattered	Cabral et al. 2005
Spain	Common	Least Concern	Rare in the south	Ruiz & Roman 1999, Moreno 2005
France	Widespread	Least Concern	Common on mainland and Corsica, rare in Bretagne	Anonymous 2009
Italy	Widespread	Near Threatened	Rare on the islands, common on mainland	Capizzi & Filippucci 2008, Bertolino et al. 2015
Slovenia	Localised	Not available	Only one record	Kryštufek 2003
Croatia	Restricted	Near Threatened	Restricted to the Adriatic coast and some islands	Tvrtković et al. 1994, 2006, Kryštufek 2003
Bosnia and Herzegovina	Not known	Not available	Information on the species' status is not available	Glasnović et al. 2009, Kotrošan et al. 2005
Austria	Localised	Least Concern	Only found in the western part of the Alps	Spitzenberger 2001, Zulka 2005
Switzerland	Common	Not considered at risk	Slight reduction after the year 2000	Duelli 1994 http://lepus.unine.ch/carto
Germany	Declining	Assumed to be Endangered	Common west of the River Rhine; rare and localised on the eastern side	Meinig et al. 2009, Meinig & Büchner 2012
Luxembourg	Localised in two areas	Not available	Present in the Moselle Valley and around the city of Diekirch (Sûre Valley)	Jörg Schlichter, pers. com.
Belgium	Restricted area but common	Endangered in Flanders; Least Concern in Wallonie	Occurs mainly in the south, sporadic in the north and in the Ardennes	Cortens 2008, Cortens & Verbeylen 2009, Maes et al. 2014
The Netherlands	Rare and localised	Critically Endangered	Only one small population	Anonymous 2007
Finland	Extinct	Regionally Extinct	Last records in the 1980s and 1990s	Rassi et al. 2010
Lithuania	Extinct	Category 0 (extinct or probably extinct)	One locality in the 1950s, no longer confirmed	Juškaitis 2003

Latvia	Rare	Category 3 (rare)	Extensive regression	Pilāts 1994, Red Data Book of Latvia 2000 http://www.latvijasdaba.lv/ziditaji/eliomys-quercinus-l
Estonia	Rare	Data Deficient	Extensive regression	Pilāts 1994, Anonymous 2008
Russia	Decreasing	Vulnerable (Leningrad region)	Isolated populations (Leningrad region)	Airapetjanc & Fokin 2002
Belarus	Rare and localised or even extinct	Vulnerable	Last record 1973	Kachanovskii 2015
Ukraine	Localised	Vanishing (Critically Endangered)	Localised in Volyn and Central Polissa	Zagorodniuk 2009
Poland	Localised	Critically Endangered	Two localities confirmed after 1950s; only one in recent years	Jurczyszyn & Wolk 1998, Pucek, 2001, http://www.iop.krakow.pl/ssaki
Czech Republic	Rare and localised	Endangered	Extensive regression	Plesník et al. 2003, Mikeš & Sedláček 2008
Slovakia	Extinct	Extinct	Latest catches before 1970s; some records in owl pellets	Žiak & Urban 2001 Obuch 2004
Romania	Rare	Vulnerable	Recent records only from Cobia Forest	Botnariuc & Tatole 2005
Bulgaria	Not present			This review
Moldova	Not present			This review