EUROPEAN RED LIST OF TERRESTRIAL MOLLUSCS: SNAILS, SLUGS, AND SEMI-SLUGS

The semislug *Vitrinobrachium breve* (LC) shown here at Elfenau, close to Bern in Switzerland. A species of forests and woodlands, it is widespread in Central and Southern Europe.
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European Terrestrial Molluscs

Europe has one of the most highly fragmented landscapes of all the continents, with only a tiny fraction of its land surface – largely the Arctic regions – considered as wilderness. Over the last 5,000 years, much of the European landscape has been shaped by human activity through food, timber and fuel production. Currently within Western Europe, more than 80% of the land area is under some form of direct management (European Environment Agency, 2007). Consequently, European species are to a large extent dependent upon semi-natural habitats created and maintained by human activity, particularly traditional, non-intensive forms of land management. Over the last century, these habitats have come under increasing pressure from agricultural intensification, urban sprawl, infrastructure development, land abandonment, acidification, eutrophication and desertification. Many species are directly affected by overexploitation, persecution, and impacts of alien invasive species, and climate change is set to become an increasingly serious threat. Europe is a vast, diverse region and the relative importance of different threats varies widely across its biogeographic regions and countries. This report is one of a series of reports on the conservation status of animals and plants in Europe, focussing on terrestrial molluscs in the Class Gastropoda – slugs, snails, and semi-slugs.

The Phylum Mollusca (snails, slugs, clams, mussels, chitons, tusk shells, monoplacophorans, polyplacophorans (chitons), Caudofoveata, Solenogastres, squids, cuttlefish and octopuses) contains an estimated 94,000 extant species worldwide. This figure comprises ca. 55,000 marine gastropods, ca. 10,000 marine bivalves, at least 25,000 terrestrial and freshwater snails and 1,300 freshwater bivalve species. The remaining groups embrace considerably fewer numbers of species, ca. 800 cephalopods, 1,100 chitons, 600 tusk shells and 420 Caudofoveata and Solenogastres (currently known and estimated numbers taken from MolluscaBase). The overall number of described species increases each year as more research is undertaken, especially in under-researched regions of the world such as the tropics. However, even within the relatively well-studied European region, new species are constantly being described, and the status of many species names, as either valid species or as synonyms of other species, needs further taxonomic study. The actual number of extant species of Mollusca globally is uncertain. Molluscs can be found in almost all habitats, from the bottom of the oceans to mountain-tops and across tundra regions. They are very diverse, not only in size and shape but also in their lifecycle, lifespan and habitat. They are an important food source for birds, fish, mammals and other invertebrates, and in some cases for humans, too. Together with such groups as the fungi and saproxylic beetles, Mollusca play a key role in soil-generation and the recycling of nutrients in natural ecosystems. Because of their often specific habitat requirements, they can be good indicators of environmental quality, especially for ancient woodlands, grasslands, wetlands and subterranean habitats. Farmers and gardeners usually view terrestrial molluscs as pests that damage plants and the subsequent control of terrestrial molluscs can cause problems from a conservation perspective. However, these ‘pest’ species actually represent only a very small fraction of the species that occur in the European region. Indeed, many of the globally significant pest species were exported from Europe to other parts of the world.

Terrestrial molluscs utilise a very wide range of microhabitats – taxa have evolved to exploit these niches, with some having very specific ecological requirements, such as interstitial spaces within subsoil, living on trees, found only on rock-faces or restricted to pristine forest habitats. The assemblage of molluscs found at a particular site is influenced by historical geographical isolation and glaciation, altitude, degree and duration of sun exposure, the quantity and duration of rainfall and the frequency of habitat disturbance (i.e., forest fires or clear-cutting, amongst many other factors).

Assessment Scope

This IUCN European Red List provides an assessment for the 2,480 species of terrestrial mollusc species known to be present in the European region at the start of 2019. Of these species, 11 are considered Not Applicable (NA) for assessment as they are not native to the European region. The number of species constantly changes as their taxonomy is revised and new species are described; a further 15-20 species have been described for the European region since this Red List assessment was completed. Updates can be found on the MolluscaBase database, which represents the taxonomic backbone used in this project.

The data presented in this report comprises 1,233 species assessed between 2009 and 2011 (Cuttelod et al., 2011) and a further 1,261 species that were assessed between 2015 and 2018 (of which 14 were first assessed in the first phase but reassessed as the result of significant new data or changes in taxonomic concept). All the assessments were made following the *IUCN Red List Categories and Criteria* (IUCN, 2001; IUCN, 2012a), which is the global standard for measuring extinction risk. For species not endemic to the EU Member States, the *Guidelines for Application of IUCN Red List Criteria at Regional and National Levels* (IUCN, 2003; IUCN, 2012b) were applied.

Red List assessments were made at two regional levels: geographical Europe ('Pan Europe'), and the Member States of the European Union. In the first stage of the *European Red List of Non-marine molluscs* (Cuttelod et al., 2011), the species were assessed at the level of the then 27 Member States of the EU (Croatia joined the EU in 2013), whilst in the second stage assessments (2015-2018), the species were assessed at the EU 28 level, with the addition of Croatia. For Pan Europe, the scope is continent-wide, extending from Iceland in the west to the Urals in the east, and from Franz Josef Land in the north to the European Macaronesian Islands in the south. The Caucasus region is not included.

The slug *Milax verrucosus* (LC) is thought to be endemic to the Stara Planina Mountains in Bulgaria. It occurs in mountains, in shaded valleys, and fairly damp places, in deciduous and mixed forests rich in litter. There are no widespread threats and it is Least Concern. © Ivailo Dedov

Levels of Endemism in Europe

The level of endemism (92%; 2,268 species) within the terrestrial molluscs of the European region is much greater than in many other taxon groups. In vertebrates, for example, the reptiles are 52.1% endemic (73 endemic species), mammals 26.9% (61 endemic species), and amphibians are 76.3% endemic (61 endemic species). There are an estimated 100,000 invertebrate species in Europe, with six groups assessed for the European Red List. The dragonflies and damselflies have a low level of endemism (12.2%; 16 endemic species), compared to Orthoptera (69.9%; 742 endemic species), and saproxylic beetles (32.4%; 224 endemic species). There are very few terrestrial mollusc species present in Europe that are not endemic to the European region, and most of these have ranges that do not extend far into North Africa or Asia. Only a few species are proven to have a holarctic distribution pattern. As a consequence, Europe and in particular those countries with single-country threatened species have a responsibility to ensure the long-term conservation of these species.

Threat Status

Overall, 21.8% and 22.5% of the 2,469 native species of terrestrial mollusc are considered threatened (species assessed as Critically Endangered, Endangered or Vulnerable) in Europe and in the European Union Member States (EU 27/28), respectively. These are the mid-point values – assuming that a similar relative proportion of the Data Deficient (DD) species are likely to be threatened – and provide the best estimate of the proportion of threatened species (IUCN, 2016). For Europe, the percentage of threatened species ranges between 19.6% (if no DD species are considered likely to be threatened) and 29.8% (if all DD species were to be assessed as threatened). The equivalent figures range from 20.1% to 30.8% for the EU27/28 Member States.

For just over one-tenth (250 species – 10.1%) of the species in Europe there was insufficient information to evaluate their risk of extinction and they were assessed as Data Deficient (DD). In the EU Member States, 240 species (10.6%) were assessed as DD, which is considerably lower than the level of data deficiency for the freshwater molluscs (24.7%) (Cuttelod et al., 2011).

In Europe, 97 species (3.9%) have been assessed as Critically Endangered, and of these, 23 species are considered Possibly Extinct (CR(PE)). A further 90 species (3.6%) have been assessed as Endangered and 296 (12.0%) as Vulnerable (Table 1 and Figure 1a). A further 14% (345 species) are considered Near Threatened. There is a very slightly higher proportion of threatened species in the EU 27/28 (4.1% Critically Endangered (23 species are CR(PE)), 3.7% Endangered and 12.3% Vulnerable), with 12.3% Near Threatened (Table 1 and Figure 1b).

Including the Near Threatened species, 37.4% of mollusc species present in the region of Europe – for which sufficient data exist – can be considered to be of elevated conservation concern. Nearly half (47.0%, 655) of all the extant species in the Member States of the European Union, are of conservation concern (threatened and Near Threatened categories).

At present, five species are considered to be extinct in the European region, all previously endemic to the Member States of the European Union, i.e. *Leiostyla lamellosa*, *Pseudocampylaea lowii*, *Vitrea storchi*, *Zonites*

The snail *Rossmaessleria scherzeri* (LC) is endemic (as the subspecies *R. scherzeri scherzeri*) to the Rock of Gibraltar. Although its distribution in Europe is highly restricted, it is assessed as Least Concern as it occurs within well-managed Protected Areas. © Marco Neiber

Table 1. Summary of numbers of terrestrial molluscs within each Red List Category.

IUCN Red List Categories	No. of species in Europe (No. of endemic species)	No. species EU Member States (No. of endemic species)
Extinct (EX)	5 (5)	5 (5)
Extinct in the Wild (EW)	0 (0)	0 (0)
Regionally Extinct (RE)	0 (0)	0 (0)
Critically Endangered (CR)	**97 (95)**	**93 (91)**
Endangered (EN)	**90 (85)**	**84 (77)**
Vulnerable (VU)	**296 (286)**	**278 (261)**
Near Threatened (NT)	345 (333)	279 (249)
Least Concern (LC)	1,386 (1,227)	1,285 (768)
Data Deficient (DD)	250 (237)	240 (204)
Total number of species	**2,469**	**2,264**

The figure (2,469) for the total of species shown in Europe excludes eleven species that are considered introduced to Europe and are therefore Not Applicable (NA). In addition, the total number of species (2,264) shown for the EU Member States excludes a further 206 species that are considered NA because they are not recorded for the Member States. It should be noted that some taxa that occur in Croatia are excluded because they were assessed prior to the accession of Croatia to the EU in 2013.

Figure 1a. IUCN Red List status of terrestrial molluscs in Europe.

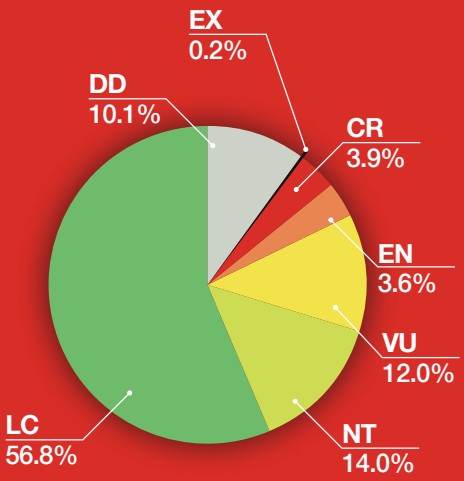
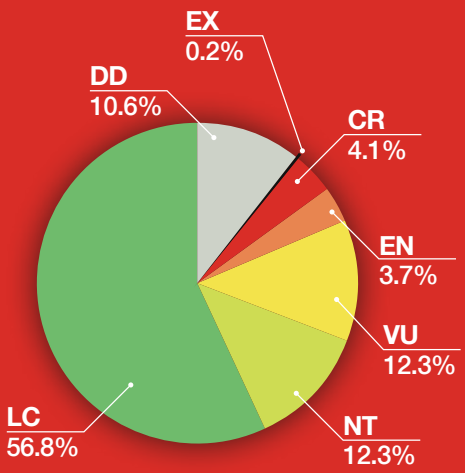


Figure 1b. IUCN Red List status of terrestrial molluscs in the EU Member States.



santoriniensis and *Zonites siphnicus*. All five species were small-range endemics from islands; the first two from Madeira and Porto Santo, the remaining three from the Aegean, the islands of Chios (*Vitrea storchi*), Santorini (*Z. santoriniensis)* and Sifnos, Sikinos and Folegandros (*Z. siphnicus*). The large species from the *Zonites* genus live on many Aegean islands, and often are single-island endemics, or inhabit a small group of neighbouring islands, as with *Z. siphnicus*. Species from the *Zonites* genus are known to have undergone seriously declines in recent decades, and many of them have not been found alive in the field. It is not clear whether their rapid extinction reflects a natural process of declining island faunas, whether it is combined with climate change, or has other causes.

The complete list of species and their Red List status in Europe and in the EU Member States (EU 27/28) is available as Supplementary Material[1].

Comparing mid-point values for other European Red List species groups that have been comprehensively assessed (Table 2) for the European region, we find that terrestrial molluscs are one of the more threatened invertebrate groups assessed for Europe so far. Only freshwater molluscs, freshwater fishes, grasshoppers and crickets, and amphibians have a higher percentage of threatened species than terrestrial molluscs; terrestrial molluscs show the highest level of endemism (92%).

[1] Supplementary Material available at: https://portals.iucn.org/library/node/48439

Table 2. Summary of the total number of species assessed, and proportion endemic, threatened, and of elevated conservation concern, ordered by the % Threatened.

Taxonomic group	Total species assessed (ex NA[1])	% Endemic	% Threatened[2] (mid-point)	% Elevated Conservation Concern[3]
Freshwater molluscs	853	87.6	58.6	69.7
Freshwater fishes	516	81.0	39.9	43.2
Grasshoppers & Crickets	1,077	68.9	28.5	43.9
Amphibians	80	76.3	24.1	40.5
Terrestrial molluscs	**2,476**	**92.0**	**21.8**	**37.4**
Lycopods & ferns	194	27.3	19.9	34.2
Reptiles	140	52.1	19.6	32.6
Mammals	227	26.9	17.6	26.6
Dragonflies & damselflies	131	12.2	15.1	26.2
Birds	543	6.8	12.1	17.7
Bees	1,942	20.7	9.2	21.2
Butterflies	437	33.0	8.6	19.0

Notes
[1] NA, Not Applicable species, usually species considered non-native to the European region. [2] Mid-point figure based on CR, EN and VU assessments. [3] Based on Extinct (EX, EW and RE), CR, EN, VU and NT assessments.

Sources
Data extracted from the original European Red Lists: freshwater molluscs (Cuttelod et al., 2011); freshwater fishes (Freyhof and Brooks, 2011); Orthoptera (Hochkirch et al., 2016); mammals (Temple and Terry, 2007); amphibians (Temple and Cox, 2009); reptiles (Cox and Temple, 2009); butterflies and bees (van Swaay et al., 2010); dragonflies (Kalkman et al., 2010); medicinal plants (Allen et al., 2015); birds (Birdlife International, 2015); marine fishes (Nieto et al., 2015); lycopods and ferns (García Criado et al., 2017); trees (Rivers et al., 2019); updated (with recent revisions and additional taxa) by M. Bilz pers. comm. 2019).

Major Threats

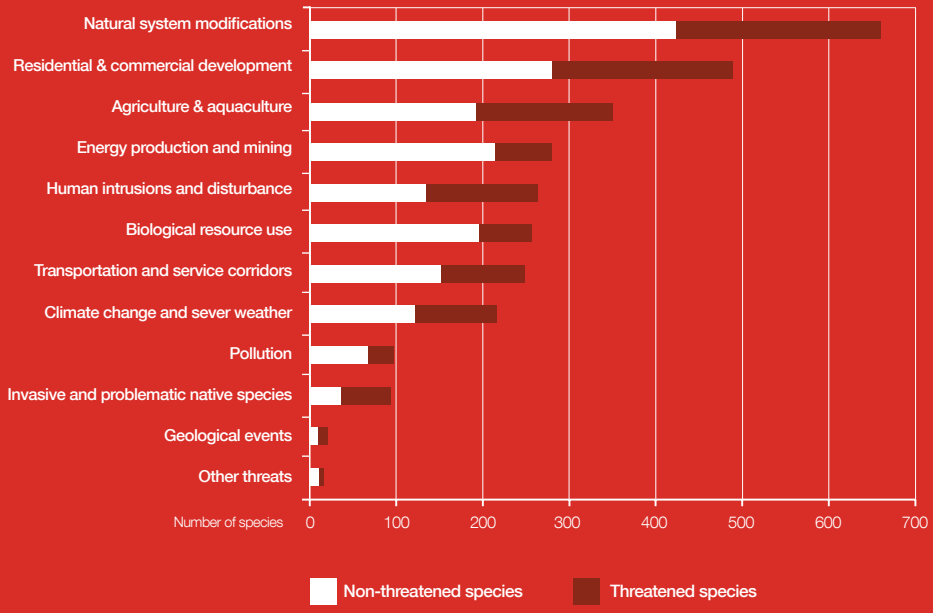
A large number of species are threatened due to their restricted range and consequential high levels of extinction risk. The ranges of many of these species do not lie in protected areas and their current conservation status is concerning.

An overview of the major threats affecting European terrestrial molluscs is shown in Figure 2.

Over 30% of all assessed species are impacted by natural system modifications, including the removal of banks and hedges, changes in fire management practices, quarrying, livestock grazing, wetland conversion and peat extraction, changes in land management practices, logging and other forest management, especially of old-growth forests.

Loss of habitats through the conversion of land to residential and industrial use is common on the edges of towns and villages. Habitats at risk include forests, meadows, fens, and marshes. Habitat loss can create additional threats to terrestrial molluscs by fragmenting forest habitats, reducing habitat area and quality; larger species of terrestrial molluscs are likely to be more at risk than

Figure 2. Major threats to terrestrial molluscs in Europe.



smaller species. Terrestrial molluscs tend to occur in meta-populations in marshes and fens, but land drainage can lead to fragmentation of riverine fringing habitats and therefore reduced opportunities for molluscs to recolonise after flooding events.

Fire within Mediterranean zones is a natural event, due to lightning strikes. However, in recent decades, the frequency and severity of fires has increased. Fire is known to cause declines in snail diversity and abundance, but given time terrestrial molluscs can recolonise when suitable vegetation re-emerges and where the burn has not destroyed the soil cover and crevices within rocky habitats. The impact of long-term climate change on fire risk and intensity requires more research. Families at particular risk include the Clausiliidae, Helicidae, Geomitridae, Hygromiidae, Enidae and Vitrinidae.

Agricultural land use has led to a decline in snail abundance, for example, where land has been drained or ploughed, rough grazing has been converted to improved grasslands, or where field boundaries have been removed to make large fields that are more economic for cultivation. The conversion of heathlands, forest and marshes/fens for agriculture use over the last 30 years further contributes to the loss of habitats for terrestrial molluscs. Families at particular risk include the Helicidae, Geomitridae, Hygromiidae, Vertiginidae and the Succineidae.

Many slug species, which are commonly regarded as agricultural pests, are threatened

Unmanaged grazing, such as shown here by a mixed herd of goats and sheep in the Slavyanka Mountains near the Izvora hut in Bulgaria, is a significant threat to some terrestrial mollusc subpopulations. © Fabia Knechtle

by the indiscriminate use of molluscicides and biological control measures. Some endemic slug species do not have large ranges, and these species are particularly vulnerable to the use of slug controls; families at particular risk include the Limacidae and the Arionidae.

Quarrying of limestone destroys large areas of crags and subterranean habitats. As many terrestrial molluscs are calciphiles, range-restricted endemics are common in limestone habitats, leading to rapid declines in populations, and potentially local or global extinctions. Families at particular risk include the Aciculidae, Cochlostomatidae, Argnidae, Clausiliidae, Lauriidae, Pupillidae, Chondrinidae and Spelaeodiscidae.

The larger terrestrial molluscs, such as *Helix pomatia, Helix lucorum, Helix figulina, Helix straminea, Helix ligata, Cornu aspersum, Otala lactea, O. punctata*, *Massylaea vermiculata* and *Cepaea nemoralis* continue to be collected for food within many of the Mediterranean countries. Some endemic species, such as the 'Chapa' (*Iberus gualtieranus*) fetch high prices in local markets, placing increasing pressure on these populations. There has been little research so far on the impact of climate change on snails and slugs, for example through fire, or through lengthening periods of no or low rainfall. This may exceed the capacity of the species to withstand drought periods, and there are anecdotal observations of this already occurring in parts of southern Europe, for example in Greece.

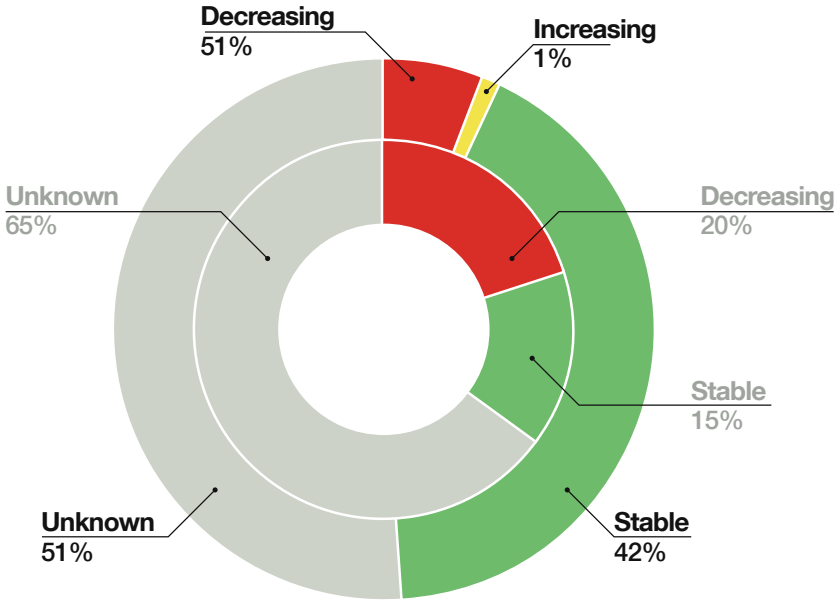
Population Trends

As part of the Red List process, the trend of each species' overall population was assessed as either declining, stable, increasing or unknown.

Data are presently very poor on the population size and trend of many species of terrestrial molluscs, largely because there are few quantitative data collected, usually for highly range-restricted island species. In some countries, there are data on general declines over 20-30 years, as distribution atlases have been published at these intervals (e.g. for the British Isles; Kerney, 1999). This is an area where citizen science projects could be launched to increase efforts in monitoring European molluscs. However, it has to be stressed that for most species of invertebrates, it is extremely hard to obtain robust data on population size, and consequently on their long-term trends!

In Europe, 6% (138 species) of terrestrial mollusc species are thought to be declining in population size, whilst 42% (1,043 species) are considered to have a stable population, however, the trend is increasing for just 1% of species and the trend is not known for more than half (1,272) of all species (Figure 3). As would be expected, the picture is worse for threatened species, with no populations thought to be increasing, 15% (70 species) stable, but 20% (97 species) with declining population trends and the trend not known for 65% (315 species).

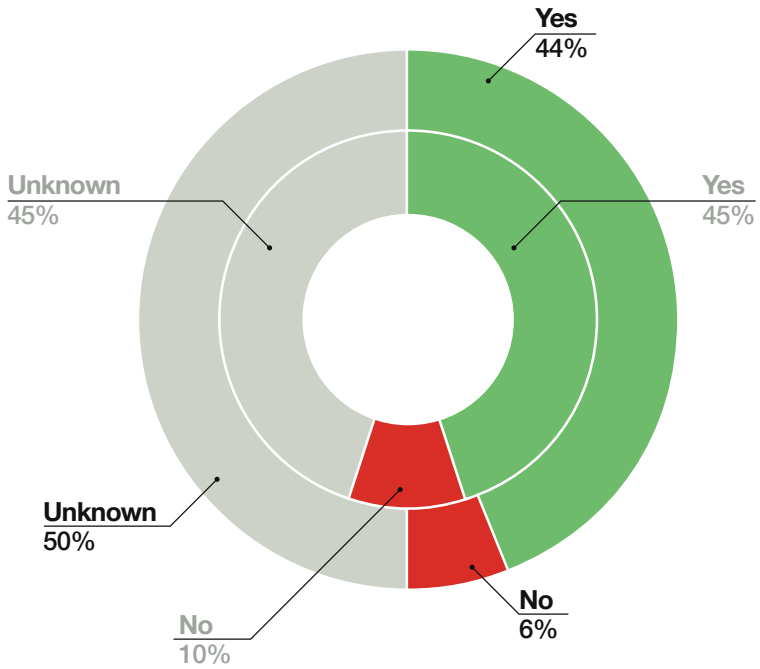
Figure 3. Population trends of European terrestrial molluscs; all species: outer ring; threatened species only: inner ring.



Protected Areas

Many species of terrestrial molluscs are recorded from protected areas (see Figure 4), however, this high figure is misleading, as there are almost no protected areas designated or managed for mollusc species. In general, only those species listed on the Habitats Directive, with a requirement to have designated Special Areas of Conservation (SACs), such as the four *Vertigo* species (*Vertigo angustior* (VU), *V. genesii* (LC), *V. geyeri* (LC), *V. moulinsiana* (VU)), *Elona quimperiana* (LC), and the Kerry Slug *Geomalacus maculosus* (LC), are species in protected areas with management plans. However, there are many species of terrestrial molluscs that are known from single sites, especially on the islands, such as in Macaronesia or the Aegean Sea, many of them threatened, that do not occur within protected areas. It is likely that the areas where these species occur would qualify as Alliance for Zero Extinction (AZE) sites, or should otherwise come within the protected areas network, and further work is required to confirm this.

Figure 4. The proportion of European terrestrial molluscs known to occur within a protected area; all species: outer ring; threatened species only: inner ring.



Spatial Distribution Patterns

The spatial distribution patterns of terrestrial molluscs in Europe are shown in Figures 5 to 8. The intermediate latitudes of central Europe clearly stand out as areas of high species richness (Figure 5). Biodiversity hotspots are located in mountainous areas such as the Pyrenees, Alps, Carpathians and the Balkan Peninsula but also on the Macaronesian Islands. The richness of endemic species is shown in Figure 6 and shows somewhat similar patterns to the overall species diversity.

The Mediterranean and Macaronesian islands have many range-restricted endemic terrestrial snails, which can also be seen on the endemic species richness map. The larger of the Canary Islands, Tenerife and Gran Canaria, as well as Madeira and Porto Santo, are densely populated by endemic species, and typically, each particular island has its own set of endemic species.

The distribution of threatened species is shown in Figure 7. Here, the pattern does not strictly follow the simple formula “the higher the species richness, the higher the number of threatened taxa”. This rule may apply for the Macaronesian islands, but certainly not for the continent. On average, the areas of high species richness “only” have a density of 2-3 threatened species per hexagon with rare spot-like exceptions populated by species of the “4-6” category. On the continent, the highest threat level is reached on the southern Pelopónnisos in Greece, reaching the maximum level of 17-24 threatened species per hexagon. This area only reaches moderate to slightly elevated values in species richness, endemicity and data deficiency (Figure 8), so the explanation for this exceptional issue is likely due to elevated environmental stress in the area, caused by fire and other factors.

Figure 5. Overall species richness of European terrestrial molluscs.

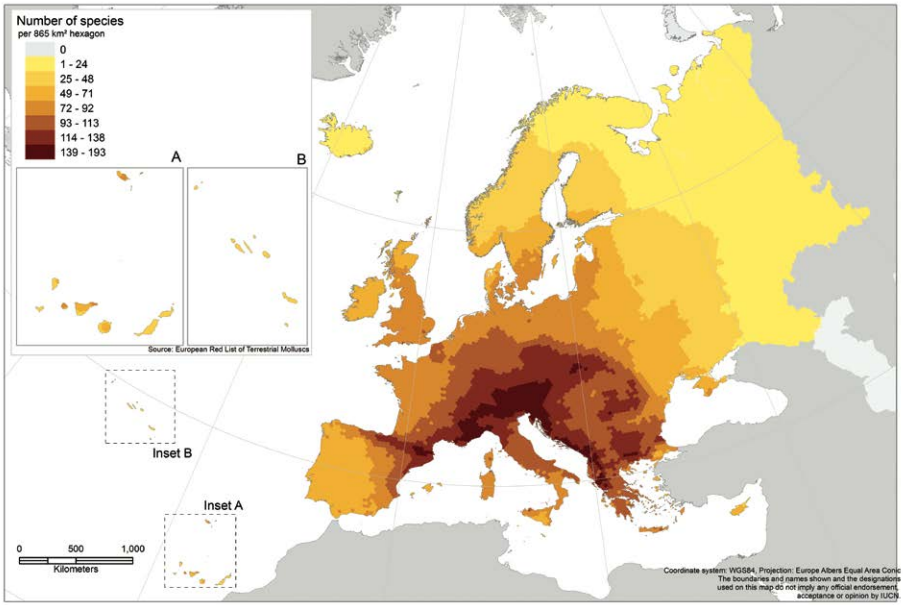


Figure 6. Distribution of endemic European terrestrial molluscs.

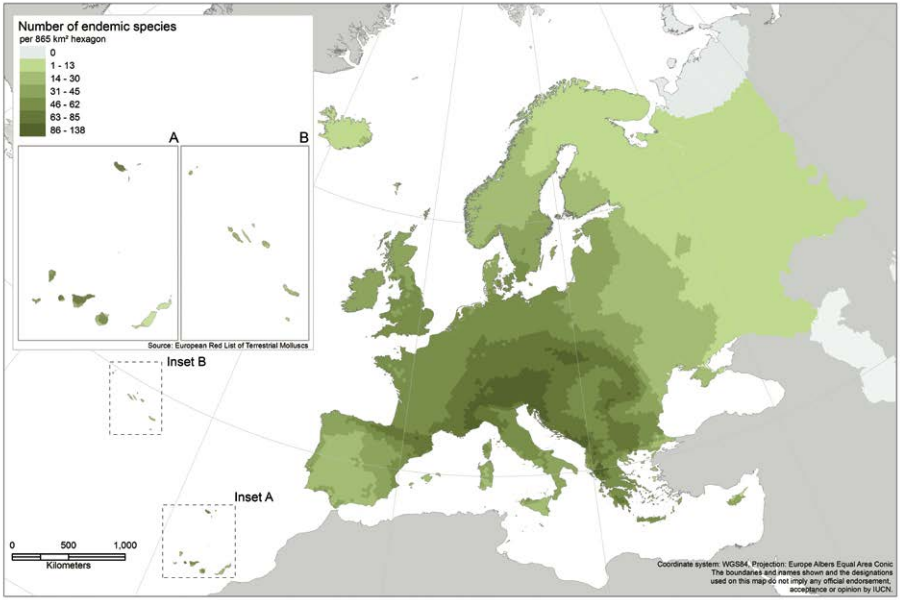


Figure 7. Distribution of threatened terrestrial molluscs in Europe.

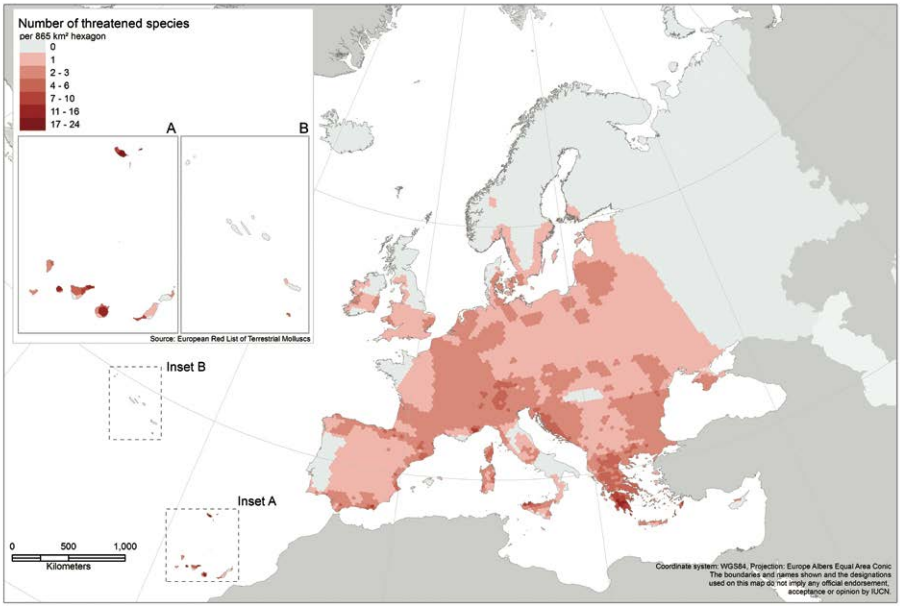
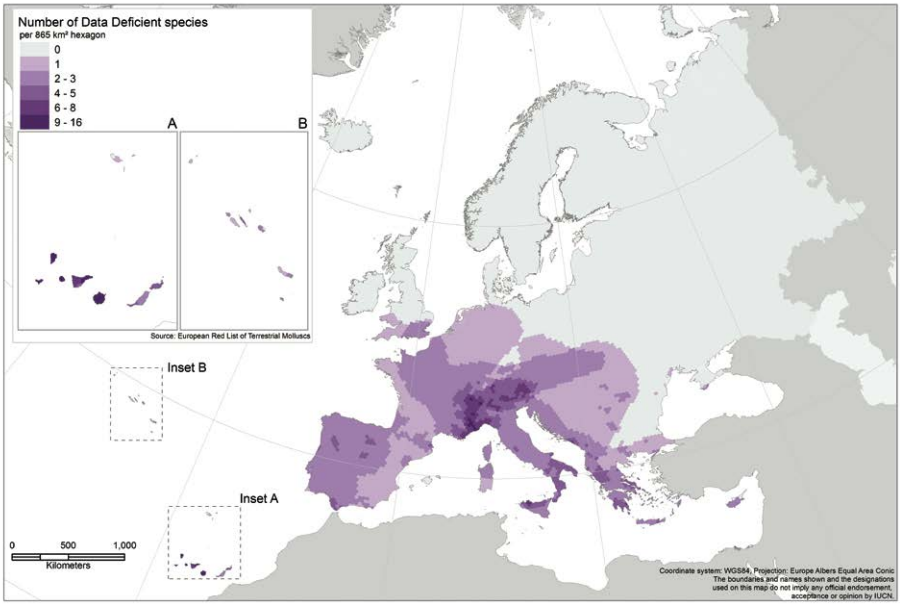


Figure 8. Distribution of Data Deficient terrestrial molluscs in Europe.



The distribution of Data Deficient species is shown in Figure 8. The Data Deficient category reflects the limited knowledge about the distribution, population or ecology of a species. The distribution pattern of these species on the continent is striking: the greatest numbers of poorly known species occur in the western and central arc of the Alps, and, to a lesser degree, in southern Italy, Sicily, and the southern part of the Balkan Peninsula. This discovery is somewhat biased as it corresponds to the area of the highest species richness and endemicity, but it occurs in countries where a well-developed scientific infrastructure is assumed to exist. A lot of effort is needed to eliminate the inflationary creation of new taxa introduced by the followers of the "Nouvelle École" in the 19th century. Another hotspot of DD species is on the Canary Islands. Despite the enormous efforts during 30 years of research by Spanish malacologists and colleagues from abroad, the knowledge on these islands and their rich malacofauna is still poor.

Conservation Actions

Legislation for species

Despite the high level of threat and endemism, just 14 of the threatened terrestrial molluscs from Europe are listed in the Habitats Directive annexes as requiring strict protection. Most taxa were placed in the Directive annexes based on data from the 1970s and have not been reviewed in recent times, except when a new country becomes a member state.

Protected Areas

It has been argued that many species will have ranges that overlap the Natura 2000 network of protected areas, which covers more than

18% of the EU's land area and hence plays a vital role in protecting species and their habitats. It is clear, however, that in practice, a Natura 2000 designation does not always mean actual protection (at least in the eastern part of Europe). Moreover, there are threatened species in habitats that lie outside protected areas, such as Natura 2000, Ramsar sites and national protected areas. This needs to be reviewed as an urgent action, to determine whether existing protected areas could have their boundaries extended or new sites developed, especially for threatened single-site (AZE) species. Habitat protection is one of the most important conservation actions needed for terrestrial molluscs at the national and international levels.

Reducing damaging operations

From a nature conservation point of view, the pivotal questions for terrestrial molluscs are the protection of existing habitats and the restoration and/or reconstruction of endangered or lost habitats. This can be seen in Figure 2 where "natural system modifications" are flagged as the major threat to terrestrial molluscs, followed by "residential & commercial development". Future conservation actions have to focus on the protection of areas rather than on individual species, as was the practice with the species listed in Annex II of the EU Habitats Directive. The management of habitats for the benefit of terrestrial molluscs, where the major threats are disturbance or destruction of the habitats, is urgently needed.

1) Logging

Logging and other forestry activities affect many forest-dependent species in Europe. In all European forest types, excessive logging deeply modifies or even destroys wood habitats. This is particularly true for sensitive species (i.e., species dependent on large standing trees, for example, or on a diverse and stable functioning forest ecosystem); forestry policy has to follow sustainable management of areas. Forest certification schemes, such as the Forest Stewardship Council (FSC), promote the

Fire, such as shown in this landscape near Trun in western Bulgaria, can completely devastate habitats and pose a significant threat to range-restricted species.
© Ivailo Dedov

responsible management of the world's forests, and many European and EU countries have certified areas, and the process is supported by the European Union Forestry Strategy. Certified forest areas must ensure the protection of threatened species in order to comply with the certification requirements, and can, therefore, play an important role in terrestrial mollusc conservation.

2) Biodiversity-friendly forest management

Forest management is also important, as it is not just logging that can impact native species of terrestrial molluscs and slugs. Dead wood is often a favoured habitat, hence removal of large trunks can be detrimental, and any woodland habitat plan should ensure that the habitats maintain a range of suitable trees of different ages, that large trunks are allowed to decay *in situ* and that clearings, and that hedges and boundary areas retain some understory vegetation and where possible link across agricultural areas. Another completely underestimated factor is the continuity in forest habitats: decaying ground litter is an important habitat, particularly for small terrestrial mollusc species. For example, species in the Vertiginidae family, and the valloniid species *Acanthinula aculeata* and *Spermodea lamellata,* are strongly dependent on ground-litter continuity in forests, especially so in Scandinavian woodlands. The role of biological or landscape corridors for the protection of terrestrial molluscs remains controversial. Landsnail dispersal may be an active process covering only short distances; here, corridors may have a fragmenting effect. However, many snails disperse passively using migrating vector species (smaller or larger mammals, fowl, human transport), so corridors may have a positive dispersal effect as well. Size, structure, and maintenance of corridors are also possible factors influencing their suitability for conservation purposes. Summarising, it can be said that biological corridors are mainly designed to serve the conservation of vertebrates, but their role for land snail dispersal and conservation needs further intensive study.

3) Biodiversity-friendly grassland management

Grassland areas host many species of endemic terrestrial molluscs. Better land management practises, such as preventing over- and under-grazing, reducing the density of stock to reduce trampling, retaining boundaries such as hedges and banks, not mowing or harvesting too frequently, and not burning off the grass and brush at inappropriate times of the year. For species-rich grassland sites, the focus should be on extensive management practices. Grassland enrichment through the introduction of nutrients (artificial fertilisers and animal manures) results in the reduction of plant species richness that then affects mollusc diversity.

4) Reducing habitat destruction by quarrying

Many terrestrial molluscs are restricted to rocky crags and hillsides, which are often sites that have the potential for limestone extraction. Planning approval for quarrying usually requires an environmental impact assessment (EIA) for biodiversity impacts, however, these frequently do not take account of invertebrate species, or only look at those listed in the EU Habitats Directive annexes. Recommended actions include undertaking an EIA if an endemic terrestrial mollusc is suspected to be present, prior to quarrying of limestone resources to ensure that these take into account biodiversity loss, especially in regions of high terrestrial mollusc endemism. It is possible to create areas that are set aside as mini-reserves within the range of a quarry region to protect the species and serve as a refuge from where terrestrial molluscs can recolonise once quarrying operations cease. However, such a fragmented landscape cannot protect subterranean or cave-dwelling species, as their subterranean habitat and especially its microclimate will be severely altered by quarrying and mining; even road construction in limestone areas is able to damage this fragile environment.

5) Reducing habitat destruction by drainage and water extraction

Many terrestrial molluscs are restricted to small calcareous fens and bogs, which

Ilhéu de Cima: a small island southwest of Porto Santo in the Madeira Archipelago, showing the effect of vegetation recovery after eradication of the feral goat population. A dense and species-rich plant community is again found on the islet, a vital prerequisite for terrestrial snail fauna.

are often sites identified as suitable for agricultural improvement. Once drainage has commenced, it is impossible for these species to recolonise, unless it is along the margin of rivers. Small areas of suitable habitat can protect these species.

Wetland habitats are often fed by springs that are identified as suitable for offtake of water for villages and agricultural purposes. Once offtake has commenced, it creates areas of dry habitat and vegetation quickly changes, such that the species sensitive to drying habitats quickly are lost in these sites. Small areas of suitable habitat can protect the species provided that the water supply is maintained at minimum levels all year around.

6) Erosion and habitat restoration

Erosion caused by a variety of factors is a widespread phenomenon all over Europe. However, it may become a critical issue where erosion affects extremely small-range endemic species. This is, for example, the case on the Desertas, a small island group off Madeira, and the other satellite islands, as well as many of the small islands and island-groups in the Aegean Sea. Trampling and massive overgrazing of vegetation by non-native species (goats) had led to serious erosion across large areas on the Madeiran islands. Consequently, mollusc populations crashed so low that they were not recorded during field surveys in the 1980s and 1990s. Today, the goat population has been eradicated, and the vegetation is now recovering slightly; recent surveys showed that many of the highly threatened terrestrial mollusc species may have survived at very low density in small pockets, and a restoration process has begun supported by the EU LIFE Programme.

Species conservation action

LIFE is the EU's financial instrument supporting nature conservation in projects throughout the EU and can, therefore, provide an important tool for conservation of terrestrial molluscs in Europe. Projects that involve a variety of actions including habitat restoration, site purchases, communication and awareness-raising, protected area infrastructure and conservation planning. Such examples are the LIFE projects operating in the Madeiran Archipelago.

Research on species trends, distribution and threats

There is a clear need to stimulate and support more research, monitoring and conservation of terrestrial mollusc species across Europe. Bilz et al. (2012: 69) stress that "…countries with the least capacity [to monitor biodiversity] tend to be custodians of the greatest quantity of wildlife. Least is known about the status of species where diversity is greatest". The opposite is true in terrestrial molluscs: as can be derived from the distribution pattern of the DD species, the least known species and the highest deficit in research is concentrated in considerably wealthy countries like France, Switzerland, Italy, and Austria.

Identification of KBA and AZE sites for terrestrial molluscs

The IUCN European Red List can be used to help prioritize sites (KBAs) and species for conservation action. At present, a KBA exercise has not commenced for terrestrial molluscs. However, given the high proportion of endemic and threatened species, it is considered that terrestrial molluscs would make ideal case studies to extend the currently identified KBAs in Europe as a whole and for the Mediterranean region specifically (Darwall et al., 2014; Máiz-Tomé et al., 2017). AZE sites should also be identified for threatened (Endangered and Critically Endangered) single-site endemic species that meet the AZE thresholds.

On the ground island conservation of snails through LIFE

Since 2010, three European Union LIFE projects (*LIFE Ilhéus do Porto Santo*, *LIFE Maciço Montanhoso*, and *LIFE Recover Natura*) have contributed to land snail conservation in the Madeira Archipelago, focusing on species listed on the EU Habitats Directive. Many of these species occur in areas where intensive habitat degradation has occurred in the form of fires, erosion, human activities, or the impact of invasive species (e.g. mice, rabbits, the Argentine Ant, or invasive plants).

Through each project, complete species inventories were produced, and accurate species distributions and populations estimates produced for the target species. The research also identified two new species of *Discula* snails, and rediscovered 'Lazarus' species (e.g. *Geomitra coronula* and *Discula lyelliana*) that had previously been considered extinct.

Conservation actions such as *ex situ* reproduction for population reinforcement (e.g. *Atlantica calathoides*), the establishment of new subpopulations of priority species based on habitat modelling (e.g. *Wollastonaria turricula),* and the introduction of artificial shelters for species protection, have contributed to the conservation of the target species. Indirect measures have played an important role in the restoration of the ecosystem equilibrium, resulting in habitat recovery and enhancing the lifecycle of the species. Interventions have included habitat recovery through the reduction or complete removal of invasive plants (e.g. *Nicotiana glauca* and *Phalaris* sp.) and animals (e.g. rabbits), which hugely impact the species habitat, and the elimination or mitigation of the impact of predators such as mice and Argentine Ant for example.

One of the most important outputs of the LIFE projects has been the implementation of monitoring schemes focused on the Habitats Directive species. For these species, a capture-mark-recapture monitoring scheme is ongoing, along with climate monitoring within each subpopulation through data loggers, and this work provides important information about the species, such as lifecycle and ecology data. In addition, ten-year species action plans were produced, encompassing the necessary measures, conservation actions and plans to ensure a good conservation status for the EU Habitats Directive species.

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Wollastonaria turricula (VU) is an example of an extreme small-range snail species, endemic to the Ilhéu de Cima, Madeira.
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Key Recommendations

Policy

- The IUCN European Red List of terrestrial molluscs should be used to inform nature and biodiversity policies to improve the status of threatened species and should be revised at regular intervals of ten years. Individual species should be reassessed whenever new data become available, for example on their distribution and novel threats, or as a result of taxonomic changes and the description of new species.
- Measures should be promoted at the EU-level to ensure the conservation of key habitats, for example, limestone habitats above and below ground, fenland areas, ancient woodlands, ancient banks and hedges and intact forest ecosystems.
- The Common Agricultural Policy should promote the appropriate management and protection of wood pasture habitats and chalk grasslands across Europe.
- Council of Europe Recommendations No R (88) 11[2] on ancient natural and semi-natural woodlands and R (88) 10[3] on the protection and management of saproxylic organisms and their biotopes

[2] Available at: https://rm.coe.int/090000168090a6bc
[3] Available at: https://rm.coe.int/090000168090a6ba

of the Council of Europe to the Member States should be fully implemented.
- Measures should be put in place to prevent illegal logging and ensure control of wood collecting.
- Guidance should be developed on best practices for terrestrial mollusc conservation in Natura 2000 sites. Threatened molluscs should be specified as species of conservation interest when they exist in Natura 2000 sites or other national/local nature reserves.

Species and habitat conservation

- Conservation strategies for European terrestrial molluscs identified to be of elevated conservation concern should be developed and implemented, especially were they are under-represented within protected areas (Trochet and Schmeller, 2013).
- Habitat fragmentation should be reduced by creating ecological networks and corridors.
- The best habitat management practices for European terrestrial molluscs should be broadly adopted and relevant stakeholders and land managers should be made more aware of the available sources of information.
- Terrestrial mollusc inventories in Natura 2000 sites and other protected areas should be made to identify priority species in order to develop strategies for their protection.
- Veteran trees should be preserved throughout Europe, in forests, pastureland, orchards, and urban areas.
- Identify those species that are known from single sites, especially those that are phyletically distinct as these are candidate species for priority actions in terms of designating KBAs and AZEs.
- EU states should review that EIA processes include evaluation of invertebrates, especially terrestrial molluscs, prior to quarrying of limestone resources to ensure that these take into account biodiversity loss, especially in regions of high terrestrial mollusc endemism.
- Environmental Impact Assessments for large dam projects should take into account biodiversity loss, in subterranean habitats especially in limestone regions that have high levels of endemism.
- Review impacts of wildfires on the loss of Mediterranean grassland species and instigate better habitat management practices for recovery of European terrestrial molluscs in regions of frequent fires.

Research

- Specific research on species that have not been recently recorded in Europe or have been assessed as Data Deficient should be conducted to clarify their status.
- The effects of poorly understood threats (e.g., climate change) on terrestrial molluscs need further study.
- Effective monitoring tools and improved research efforts on terrestrial mollusc species should be developed and promoted, particularly in the Natura 2000 network, in order to understand population trends and the impacts of implemented actions.
- Further research is needed to identify and protect old growth habitats in the cultural landscapes of Europe.

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The LIFE Programme (https://ec.europa.eu/easme/en/life) is the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental, nature conservation and climate policy and legislation by co-financing projects with European added value.

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Alinda wagneri (LC) – is endemic to the western parts of the Stara Planina Mountains in Bulgaria and Serbia. It is assessed as Least Concern.
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