THE CONSERVATION STATUS AND DISTRIBUTION OF MEDITERRANEAN DUNG BEETLES

Catherine Numa, Mattia Tonelli, Jorge M. Lobo, José R. Verdú, Jean-Pierre Lumaret, Francisco Sánchez-Piñero, José L. Ruiz, Marco Dellacasa, Stefano Ziani, Alfonsina Arriaga, Francisco Cabrero, Imen Labidi, Violeta Barrios, Yakup Şenyüz and Sinan Anlaş

MEDITERRANEAN

The IUCN Red List of Threatened Species™ – Regional Assessment

SSC
Species Survival Commission

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THE IUCN RED LIST OF THREATENED SPECIES™ – REGIONAL ASSESSMENT

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Cover photo: *Ceratophyus martinezi* is considered Endangered. It is threatened by habitat degradation due to traditional farming abandonment and conversion to *Eucalyptus* plantations. © J.R. Verdú
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Thorectes valencianus, an apterous endemic species from south-east Spain, associated with rabbit latrines and traditional pastoralism. Listed as Vulnerable © J.R. Verdú

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Foreword

The Mediterranean Basin is home to many animals and plants that are found nowhere else on Earth. It is also recognised as a Global Biodiversity Hotspot, an area that besides being extremely rich in biodiversity is also under threat. People have lived in the Mediterranean for thousands of years and have turned it into a mosaic of natural and cultural landscapes. However, in recent decades the region has been put under tremendous pressure due to the growing human population, abandonment of the countryside, growth of industrial agriculture and intensive livestock production, widespread use of chemicals to increase productivity and climatic changes. As a result of all these processes the Mediterranean Basin is recognised as one of the four most significantly altered biodiversity hotspots in the world. In this changing scenario, it is critical to understand how wild plants and animals are faring, what the main threats affecting their populations are, and which conservation measures are in place, or should be implemented, to minimise their extinction risk. Assessing the conservation status of species at the Mediterranean level is particularly important to guide and inform regional policy instruments. The IUCN Red List of Threatened Species™ is an important way to monitor progress towards achieving the new global Sustainable Development Goals[1], in particular numbers 14 and 15 which seek to halt marine and terrestrial biodiversity loss. The Mediterranean Red List is a regional initiative focused on assessing the extinction risk of species in the Mediterranean Basin. It is in the Mediterranean region where, 10 years ago, IUCN developed its first regional Red List[2] with the support of the MAVA Foundation, a successful model that was later replicated in other regions. Several groups have already been comprehensively assessed, namely mammals, reptiles, birds, freshwater fishes, cartilaginous fishes, crabs and crayfish, and dragonflies.

We need to expand our knowledge of the status of biodiversity in the Mediterranean by adding information about hyperdiverse invertebrate groups that are easy to identify and can serve as indicators of altered natural landscapes. Recent findings showing the relationship between dung beetle diversity and human-induced changes confirm why this charismatic and very visible group of species is one of the indicator groups that was missing. *The Conservation Status and Distribution of Mediterranean Dung Beetles* is the latest addition to the already impressive number of species assessments at this regional level. Adding another invertebrate group also helps make the Mediterranean Red List more representative of the region's overall biodiversity. There are more than 644 recorded dung beetle species in the Mediterranean region, of which 150 are endemic. This publication reveals that about 20% of the species assessed may be threatened with extinction, including 25% of the endemic species. The main threats to dung beetles are habitat loss and chemical pollution by veterinary medical products due to changes in the management of semi-natural grasslands through intensification of farming, overgrazing or the abandonment of livestock grazing. However, for 37% of the species there was not enough available information to assess their extinction risk, and these species were classified as Data Deficient. Regional cooperation among Mediterranean countries is urgently needed to improve our knowledge of the status of all dung beetle species and to minimise their extinction risk throughout the Basin. I hope this publication will serve decision makers as a source of sound scientific data for policy development and natural resource management, and that it will provide a basis for future conservation work on Mediterranean dung beetles. In addition, I hope it will inspire people to learn more about and care for these remarkable creatures.

Ana Nieto
Head of Species Conservation Action
IUCN Global Species Programme

[1] https://sdgs.un.org/goals
[2] https://www.iucnredlist.org/regions/mediterranean

Foreword

The Mediterranean is a region rich in natural and cultural heritage, characterised by high levels of species diversity and endemism. It is the second largest of the 34 biodiversity hotspots in the world. It stretches across more than 25 countries, including major terrestrial habitats such as forests, maquis, garrigue, pasture, wetlands, coastal areas and areas of transition (ecotones) between each of these and desert zones.

IUCN, as a global organisation, is the leading provider of biodiversity knowledge, tools and standards used to influence policy, undertake conservation planning and guide action on the ground. Knowledge is key and the IUCN Centre for Mediterranean Cooperation (IUCN-Med) works to leverage its knowledge, standards and tools to influence policy and to support action in the Mediterranean region, particularly where these measures are undertaken by IUCN Members. Better knowledge about biodiversity, including threats and conservation measures, will help drive action. By combining credible knowledge, standards and tools with a readily mobilised network of Members and partners, real change in policies and action on the ground to conserve biodiversity is possible. In that context, Regional Mediterranean Red Lists are an important tool for scientifically assessing and communicating the status of species. They provide comprehensive information about the situation of biodiversity in the region and are an important practical mechanism for implementing national and regional strategies for biodiversity conservation under the Convention on Biological Diversity. Mediterranean Red-Listing will keep contributing to the post-2020 global biodiversity framework, in particular to those targets which calls for the prevention of extinction of known threatened species and improvement of their conservation status. Mediterranean Red List assessments are carried out in partnership with organisations and individuals around the region and will help to deliver these various targets. The current Mediterranean landscape and the remarkable natural richness of the hotspot are a consequence of the intense interaction between human beings and the natural world that has been taking place over millennia. Although it has brought about higher diversity, this modification has also placed great pressure on wildlife and natural areas. For example, more than 50% of wetlands are reported to have disappeared over the past century, and their decline and deterioration continue. Local species depletions have mostly occurred among larger species, including marine mammals, birds, turtles, commercial fish and invertebrates.

Dung beetles are key organisms for Mediterranean ecosystems to function in that they provide several environmental services vital to human well-being, such as soil nitrification, soil aeration, dung removal, secondary seed dispersal, parasite control and the reduction of greenhouse gas emissions. This report presents a review of the conservation status of 200 species of native dung beetles in the Mediterranean biodiversity hotspot undertaken by experts from around the region. Since its establishment in 2001, the primary role of IUCN-Med has been to assess the regional conservation status of selected taxonomic groups. The Red List of dung beetles is the 13th publication in the series. The assessment shows us that at least 25 species are threatened with extinction in the region. Unfortunately, the drivers for these declines are still in place. The conversion of grasslands into agricultural land for arable farming or forestry, unsustainable levels of intensive grazing, the indiscriminate use of veterinary medical products and the abandonment of livestock farming are important threats to these species. This Red List is further evidence that efforts to halt biodiversity loss in the region need a major boost in the coming years to safeguard our natural capital for future generations.

Antonio Troya
Director
IUCN Centre for Mediterranean Cooperation

Executive summary

Aim

The Mediterranean Red List assessment is a review of the regional conservation status of approximately 6,000 species (amphibians, mammals, reptiles, birds, fishes, butterflies, dragonflies, beetles, corals and plants) according to the IUCN Red List Categories and Criteria. It identifies those species that are threatened with extinction at the regional level to guide appropriate conservation actions for improving their status. This report summarises the results for Mediterranean dung beetles.

Scope

All the dung beetles that are endemic or nearly endemic to the Mediterranean region – 200 species – are included. The geographical scope is the Mediterranean region according to the Mediterranean Basin Biodiversity Hotspot (Mittermeier et al., 2004), with the exception of the Macaronesian islands, which have not been included in this study.

Conservation status assessment

Species conservation status was assessed using the IUCN Red List Categories and Criteria (IUCN Species Survival Commission, 2001). The assessments followed the guidelines for application of the Categories and Criteria at regional levels (IUCN Species Survival Commission, 2003). They were compiled by a network of 15 regional experts, reviewed during a workshop held in the Doñana Biological Reserve (Spain) and followed up through correspondence until completion. All individual taxon assessments have been published on the IUCN Red List website: https://www.iucnredlist.org/regions/mediterranean

Mediterranean dung beetles

Of the 644 species of dung beetles inhabiting the Mediterranean region, 200 (32%) have at least 75% of their distribution range within the borders of the region. The other 444 species, which occur over a wider area, were excluded from this assessment. Of the 200 species analysed, 150 are considered endemic as they cannot be found anywhere else in the world.

Results

Overall, 25 of the 200 dung beetle species evaluated are threatened in the Mediterranean region. Fourteen species are classified as Near Threatened (NT) and 74 species as Data Deficient (DD). Assuming that a similar proportion of the DD species are likely to be threatened, it is estimated that 20% of dung beetles are threatened in the Mediterranean region. This percentage of threatened species is lower than in other terrestrial groups assessed in the region, such as saproxylic beetles (32%), amphibians (30%) and reptiles (22%), but higher than in better-known groups like mammals (13%) or butterflies (5%).

The Mediterranean region also has a high level of endemicity for dung beetles, with 150 species (24%) found nowhere else in the world; 21 (14%) of these endemic species are threatened with extinction.

Jekelius castillanus,an apterous dung beetle endemic to gypsiferous soil steppes of Central Spain associated with rabbit populations and traditional pastoralism. Listed as Endangered. © J.R. Verdú

A preliminary analysis of spatial patterns shows that the areas with the highest numbers of endemic species are northern Africa and the southern Iberian Peninsula. A hotspot of threatened dung beetles coincides with coastal habitats located in the southern and eastern Iberian Peninsula, the island of Sardinia and along the Atlantic and Mediterranean coasts of North Africa from Morocco to Tunisia.

The current main threats to Mediterranean dung beetles are habitat loss and chemical contamination of dung by veterinary medical products due to changes in the management of semi-natural grasslands through intensification of farming, overgrazing or the abandonment of livestock grazing. Other important threats are the development of urban infrastructure, especially in coastal areas, and infrastructure corridors. There is a significant lack of information on distribution, population size and threats for many Mediterranean species, especially in the southern and eastern Mediterranean, many of which may prove to be threatened as well.

Conclusions and recommendations

Despite their key role in ecosystem functioning and food web dynamics, dung beetles are still poorly understood and the current information gaps regarding these species´ population status, trends and geographical distribution reflect how little we still know about them. Overall, the main impacts of current land use changes due to agricultural intensification, overgrazing, livestock abandonment and urban development are the degradation and disappearance of dung beetle habitats. One particular aspect of agricultural intensification – pollution in livestock faeces as a consequence of the indiscriminate use of veterinary medical products – has been identified as the main emerging threat to Mediterranean dung beetle diversity. Recommended conservation actions to improve dung beetle species' status include:

- Revising national and international legislation to include those threatened species identified in this assessment, bearing in mind that collecting for scientific purposes is fundamental for their future conservation.
- Developing legislation to regulate the use of veterinary medical products for parasite control, and measures to prevent their administration from causing pollution.
- Prioritising fieldwork and data collection for Data Deficient species to determine whether they need conservation actions.
- Drawing up species/habitat action plans for the most threatened species.
- Expanding the funding mechanisms (e.g. EU Life programme) to cover conservation projects benefiting threatened dung beetles on the IUCN Red List.
- Initiating dung beetle monitoring in different parts of the Mediterranean. Only regular counts provide reliable data for the detailed monitoring of dung beetle populations.
- Promoting organic farming of native breeds within the agro-silvo-pastoral system, by applying measures that guarantee the environmental safety of the coprophilic fauna in the case of a veterinary chemical treatment.
- Raising awareness about the importance of dung beetle biodiversity in maintaining healthy rangelands.
- Ensuring the continuation of strong regional cooperation among experts and starting new cooperation efforts with experts from countries where information is scarce, so that this initial assessment of the conservation status of native Mediterranean dung beetles can be updated as new information becomes available.

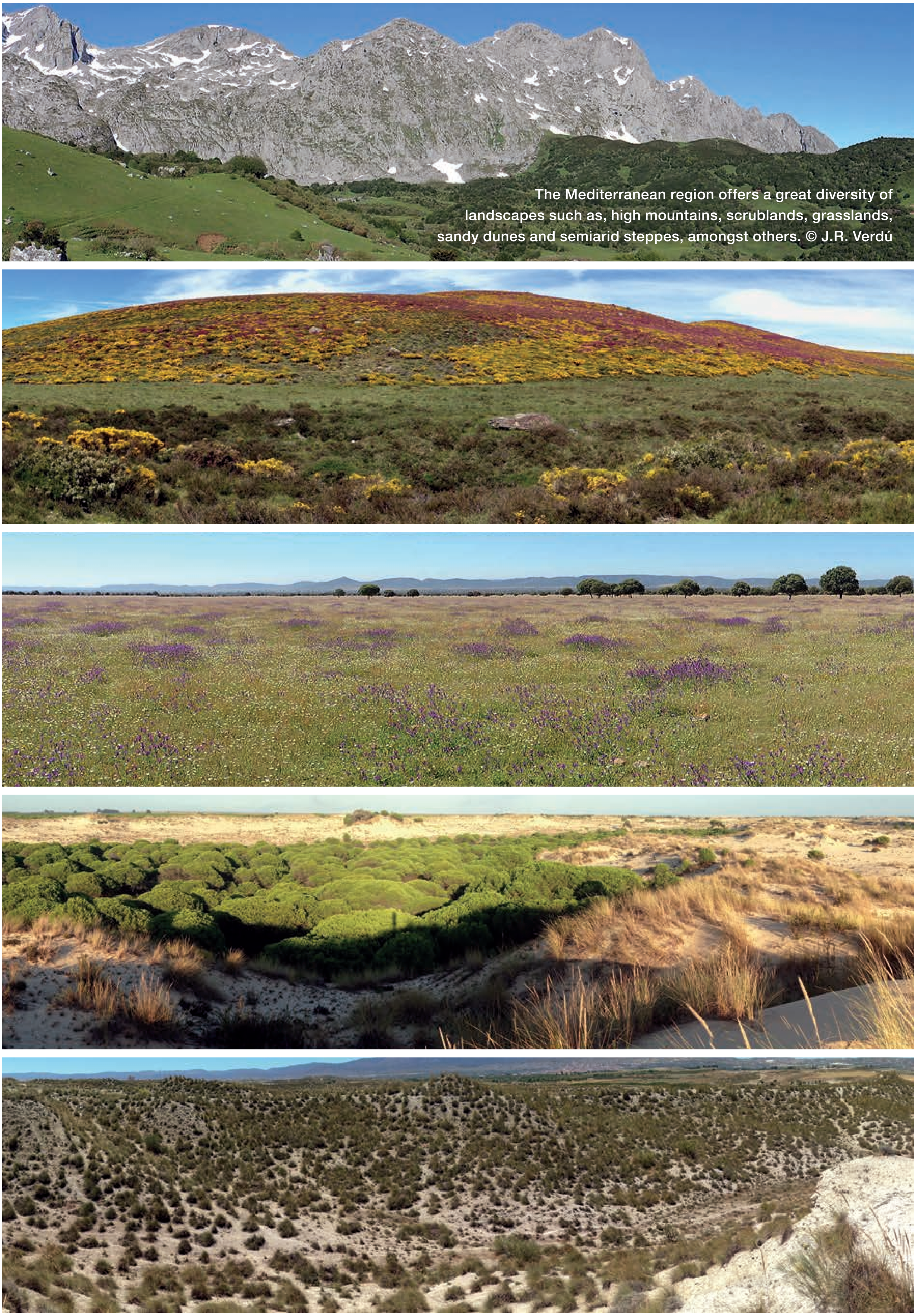
Key messages

Dung beetles are one of the main components of the soil fauna. They are involved in important ecosystem services such as breaking down organic matter and nutrient recycling, sequestering carbon in the soil, reducing methane emissions from dung pats and contributing to the insect biomass available to feed higher trophic levels, such as breeding birds, bats and other insectivorous vertebrates.

Information on many dung beetle species in the Mediterranean region remains very limited, with 37% of the assessed species being classified as Data Deficient (DD). There is an urgent need for collaborative field research and monitoring. Given the high threat levels throughout the Mediterranean region, it is reasonable to expect that further research and sampling will reveal many of these DD species to be threatened.

Dung beetle diversity in the Mediterranean region is highly dependent on landscape heterogeneity, the variety of mammals present and the availability of unpolluted herbivore dung pats. Improved domestic and natural grazing management in natural and agricultural landscapes will be key to conserving soil biodiversity to ensure future healthy ecosystems.

Two individuals of *Thorectes lusitanicus* feeding on an acorn of *Quercus suber* in Los Alcornocales Natural Park (Southern Spain). This species, along with others *Thorectes* species, are important for the dispersal of acorns, their burial and germination. Listed as Near Threatened © J.R. Verdú


The Mediterranean region offers a great diversity of landscapes such as, high mountains, scrublands, grasslands, sandy dunes and semiarid steppes, amongst others. © J.R. Verdú

1. Introduction

This report comprises a summary of the regional conservation status of dung beetles in the Mediterranean Basin. The IUCN Centre for Mediterranean Cooperation, in collaboration with the IUCN Species Programme and a key group of regional experts, presents the overall results and findings of the regional Red List assessment. The objective of this report is to provide the baseline status of this group of beetles in the region. It includes information about their distribution and natural history, and highlights those species that have been found to be of greatest conservation concern. It also reveals that very little or no information is available for a large number of species, for which more research and awareness is urgently needed. It is envisaged that the information contained within this report will facilitate the development of priority research, conservation and management actions for the region.

1.1 The Mediterranean region

The Mediterranean Basin stretches approximately 3,800 km from the tip of Portugal in the west to the shores of Lebanon in the east, and approximately 1,000 km from Italy in the north to Morocco and Libya in the south. It includes 25 countries historically connected by a common sea, spread across three continents.

Environmental conditions in the Mediterranean Basin have a profound influence on the vegetation and wildlife of the region. The climate is characterised by hot, dry summers and cool, wet winters, and the topography is varied and contrasting (UNEP/MAP, 2013). The Mediterranean region offers a changing landscape of high mountains, rocky shores, scrubland, semi-arid steppes, coastal wetlands, sandy beaches and a myriad of islands of various shapes and sizes. The landscape is a direct result of centuries of human-induced activities, such as forest fires, clearance, livestock grazing and cultivation (Zeder, 2008; Sundseth, 2009). The region is one of the world's richest places in terms of animal and plant diversity, with a high level of endemism (Myers et al., 2000).

About one-third of the outstanding diversity of the Mediterranean region consists of endemic species, including 60% of its freshwater mollusc species, almost half of its amphibians and freshwater fishes, 41% of its reptiles, 21% of its butterflies, 13% of its dragonflies, 12% of its mammals and 2% of the birds inhabiting the region (Critical Ecosystem Partnership Fund, 2017). Underwater, the Mediterranean Sea´s biodiversity is exceptionally rich, harbouring up to 18% of the world's macroscopic marine species. Of these, 25–30% are endemic (Bianchi & Morri, 2000), including 14% of the region's marine fish species (Dulvy et al., 2016; Abdul Malak et al., 2011). The Mediterranean's importance for wildlife is not limited to the richness and uniqueness of its resident fauna and flora, as millions of migratory birds from the far reaches of Europe and Africa also use Mediterranean wetlands and other habitats as stopover, wintering or breeding sites (Cuttelod et al., 2008).

A basic characteristic of the Mediterranean region is its long, close association with human activities that have moulded its landscape and now deeply influence the sustainability of its biodiversity. The region is currently home to around 480 million people and is visited by an additional 285 million tourists a year (figures for 2010: European Environment Agency, 2014). Population growth and tourism have not only caused the loss of wildlife-rich habitats by increasing urbanisation and tourism infrastructure, but have also contributed to chronic water shortages and had a major socio-economic impact on large parts of the region (Numa et al., 2016).

In particular, a massive change has taken place in agricultural and livestock production systems across the Mediterranean over the last 50 years (Strijker, 2005). Ancient vineyards, orchards, cork-oak woodlands and olive groves have been cleared to make way for industrial-scale fruit or olive plantations, while mixed rotational farming has been replaced by intensive monocultures (Sundseth, 2009). Similarly, profound changes in livestock production systems have led to intensification of grazing in some areas, such as North Africa (Ben Salem, 2011) and the Middle East (Mohamed et al., 2019), as well as industrialisation and the abandonment of traditional extensive and semi-extensive livestock grazing in others (Bernués et al., 2011). Modern farming practices also put an inordinate amount of pressure on the surrounding environment through their high demand for pesticides, fertilisers and irrigation water (FAO, 2017). More than 26 million ha of farmland are now under irrigation in the Mediterranean Basin and in some areas up to 80% of the available water is used for irrigation, causing severe overexploitation of both ground and surface waters (Sundseth, 2009).

BOX 1

INSECT POPULATION DECLINE: EVIDENCE FROM DUNG BEETLES

There are serious concerns about the decline of insect populations and biomass, the extinction of some species and shifts in the composition of insect assemblages (Hallmann et al., 2017; Sánchez-Bayo & Wyckhuys, 2019; Goulson, 2019). Although this evidence should be treated with caution due to the spatial and temporal bias and scarceness of the available data (Habel et al., 2019), it presents an alarming picture. In the case of dung beetles, some older studies already suspected that the decline of these species was associated with land use changes and the abandonment of traditional livestock practices in Europe (Johnson, 1962; Leclerc et al., 1980; Lumaret, 1990; Väisänen & Rassi, 1990; Biström et al., 1991; Lumaret & Kirk, 1991; Miessen, 1997). A more exhaustive analysis of the roller dung beetles collected in the Iberian Peninsula during the 20th century (Lobo, 2001) showed a decline in the abundance of populations and a contraction in their distributional ranges (Figure 1). Further analyses in the French Camargue (Lobo et al., 2001) and Italy (Carpaneto et al., 2007) corroborated these patterns. The main causes mentioned for this decline are related to the anthropisation of the landscape and the abandonment of traditional pastoral practices (see Box 5), while the harmful effects of veterinary medical products are also becoming increasingly evident (see Box 6).

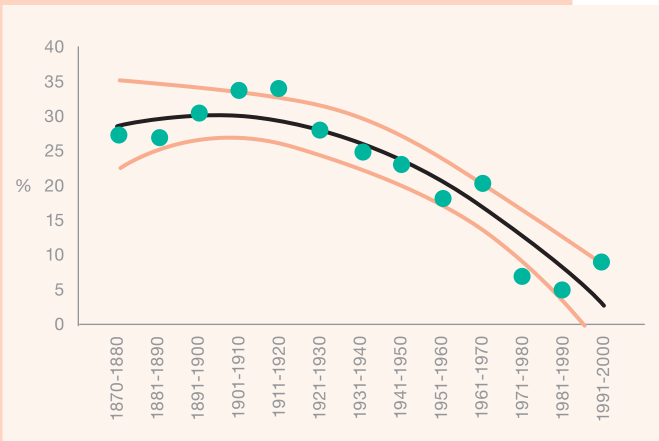


Figure 1. Decadal-scale variation in the percentage of records of roller dung beetles in the Iberian Peninsula over total Scarabaeidae database records. Data from BANDASCA, freely available at GBIF (Lobo, 2001).

In order to effectively monitor the changes in the distribution and abundance of Mediterranean dung beetles, there is a need for standardised protocols aimed at obtaining long-term data or, failing that, inter-annual comparisons with surveys carried out many years ago. Comparisons carried out in Europe (Agoglitta et al., 2012; Dortel et al., 2013; Menéndez et al., 2014; Birkett et al., 2018; Cuesta & Lobo, 2019) have detected a moderate compositional turnover, probably as a consequence of vegetation and climatic changes, together with a relative decrease in the populations of large-bodied species.

Water scarcity, the concentration of economic activities in coastal areas and the region's dependence on climate-sensitive agriculture make the Mediterranean particularly susceptible to climate change; its effects are expected to worsen the ongoing impacts of water stress and extreme weather events such as floods and droughts (European Environment Agency, 2014).

Human population growth, changes in traditional land use (e.g. agricultural intensification and grazing abandonment; see Box 5), overgrazing, invasion of non-native species, fires and the inordinate growth of tourism infrastructure are some of the main human-induced changes that are putting an ever-increasing number of Mediterranean species at high risk of extinction (IUCN, 2017). The decline of dung beetle populations in the Mediterranean has been demonstrated by several studies (Box 1). Furthermore, the expansion of industrial livestock production and the ubiquitous use of veterinary medical products in almost all types of farming are also very important extinction risk factors for Mediterranean dung beetles (see Box 6).

1.2 Natural history, ecology and biogeography of dung beetles

Dung beetles are a large group of insects belonging to the order Coleoptera, which means 'sheath-wing'. They are characterised by a variety of shapes and sizes ranging from 1.5 millimetres to 5–7 centimetres for the largest species (Ratcliffe et al., 2002, Pokomý et al., 2009). The common feature of all the species belonging to this group is the type of resource used for feeding and nesting: the dung of mammals, mainly herbivores. To exploit these ephemeral resources, dung beetles have particular adaptations such as being strong fliers, which in some species are associated with an endothermic system that maintains a stable body temperature regardless of ambient temperature (Bartholomew & Heinrich, 1978); life cycles that allow survival during unfavourable periods (O'Neill, 2016); a strong olfactory sense to detect faeces (Tribe & Burger, 2011); various strategies for using dung to reduce competition (Halffter & Edmonds, 1982; Hanski & Cambefort, 1991); and also the ability to rapidly adjust their population size to the amount of resources available (Lumaret et al., 1992).

The beetles exhibit different behaviours to exploit faeces, allowing them to be classified into three main functional groups (Halffter & Edmonds, 1982): a) dwellers, species that feed and breed within the dung mass; b) tunnellers, species that construct tunnels from beneath the pat which are filled with dung for feeding or nesting; and c) rollers, species that transport balls of dung some distance away from the pat before burying them in the ground. Generally, dung beetles lay a number of eggs that is inversely proportional to the degree of parental care. When the eggs hatch, the larvae begin to feed on the dung before pupating, undergoing metamorphosis and becoming adults.

Dung beetles play a crucial role in ecosystems as decomposers and they are also of economic importance in natural and agricultural ecosystems. It has been estimated that dung beetles provide benefits worth US$ 350 million yr-1 to the US livestock sector (Losey & Vaughan, 2006) and an amount within the same order of magnitude (€412 million yr-1) to the UK cattle industry (Beynon et al., 2015). Dung beetles are involved in numerous ecological functions, such as nutrient recycling (Yokoyama et al., 1991), soil improvement (Mittal, 1993), seed dispersal (Andresen, 1999), pest control (Miller et al., 1961) and reduction of methane emissons (Penttilä et al., 2013; Verdú et al., 2020) (see Box 2).

Dung beetles are also considered good indicators for environmental assessment due to their ease of collection, accessible literature for identification, broad geographical distribution and graded response to environmental changes (Halffter & Favila, 1993; Spector, 2006).

Dung beetle is a generic name for a member of a species belonging to the Aphodiinae and Scarabaeinae subfamilies of the Scarabaeidae family and also the Geotrupinae subfamily of the Geotrupidae family (Table 1, Figure 2). The Aphodiinae are generally small beetles (1.5–15 mm) comprising mostly dung dweller species, the larvae of which are often not strictly coprophagous. Scarabaeinae is a very heterogeneous subfamily in terms of morphology and size; its species are mainly tunnellers and rollers. Finally, Geotrupinae species are medium to large in body size (10–30 mm), with relatively homogeneous morphology and tunnelling behaviour; they are also able to feed on food sources other than dung. Some members of this subfamily (e.g. the genera *Thorectes* and *Lethrus*) are apterous (wingless).

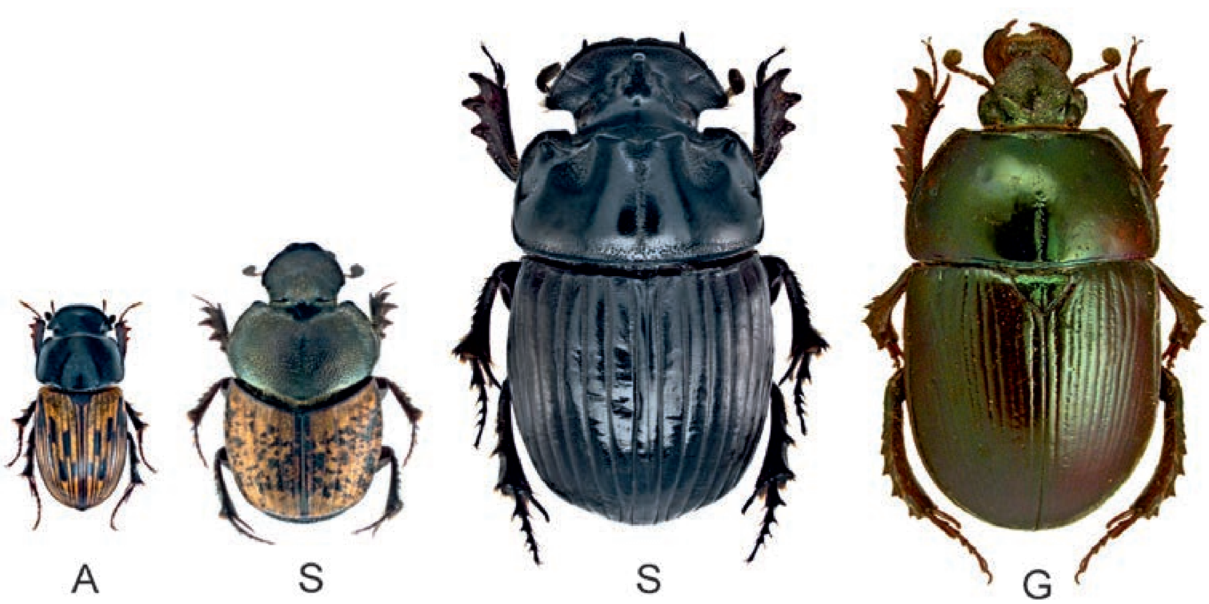


Figure 2. Typical morphology of dung beetle species belonging to the Aphodiinae (A), Scarabaeinae (S) and Geotrupinae (G)

According to fossil evidence and age-calibrated phylogenies, the Scarabaeinae subfamily of dung-consuming specialists had a Lower Cretaceous origin (≈130 My) in the warm region of Gondwanaland, and subsequently diversified during the Cenozoic in response to the diversification of mammals (Ahrens et al., 2014; Davis et al., 2002; Davis et al., 2017). This implies that these beetles had originally consumed dinosaur dung once angiosperms provided more nutritious and less fibrous foliage (Gunter et al., 2016). The Geotrupinae and Aphodiinae are believed to be equally ancient – ≈130 My and 145 My, respectively (Cunha et al., 2011; Gunter et al., 2016) – although they contain species with saprophagous habits that probably diversified under cooler conditions.

A male *Ceratophyus martinezi*. This species inhabits in *Quercus pyrenaica* wet forests in the Iberian Central System. Listed as Endangered. © J.R. Verdú

BOX 2

ECOLOGICAL FUNCTIONS AND ECOSYSTEM SERVICES PROVIDED BY DUNG BEETLES

Among the biological agents of the complex dung food web, dung beetles (Coleoptera Scarabaeoidea, subfamilies Scarabaeinae, Geotrupinae and Aphodiinae) are one of the dominant and most effective dung-decomposing insect groups. Dung beetle populations play key roles in the maintenance of agro-ecosystems, contributing significantly to key ecological processes such as:

- Nutrient cycling: Ammonia volatilisation and nitrogen mineralisation are bacterial-mediated processes, and dung beetles modify the assemblages of microorganisms in dung pats and breeding masses/balls during feeding and nesting (Yokoyama et al., 1991).
- Soil bioturbation and aeration: Dung beetles play a role in bioturbation by moving large amounts of soil to the surface during nesting (Mittal, 1993).
- Greenhouse gas emissions: dung beetle activity significantly reduces total CO_2 and CH_4 emissions from dung pats in Mediterranean ecosystems (Verdú et al., 2020). A pivotal requirement for sustainable management in the livestock sector is maintaining the diversity of dung decomposer insects, since a decrease in their ecological activity is responsible for an increase in greenhouse gas emissions (Penttilä et al., 2013; Verdú et al., 2020).
- Parasite control: The passage of dung through certain species of dung beetles significantly reduces the abundance of viable helminth eggs and protozoan cysts, including *Ascaris lumbricoides, Necator americanus, Trichuris trichiura, Entamoeba coli, Endolimax nanus* and *Giardia lamblia* (Miller et al., 1961). Indeed, the contribution of dung beetle activity to the ecosystem service of gastrointestinal parasite management has been estimated to save the UK cattle industry around €412 million each year (around €397 million in conventional livestock systems and around €15 million in organic livestock systems; Beynon et al., 2015).
- Fly control: Adult beetle feeding reduces fly numbers by causing direct mechanical damage to fly eggs and early instars (Ridsdill-Smith & Hayles, 1990).
- Plant growth: Dung beetles mix dung with soil, which results in significant increases in plant height (Galbiati et al., 1995; Nervo et al., 2017); dung beetle activity even outperformed chemical fertiliser application in increasing plant height and leaf production (Rougon et al., 1988; Miranda et al., 2000).
- Secondary seed dispersal: Dung beetles relocate seeds from the point of deposition, increasing seed survival and reducing seed predation and mortality (Andresen, 1999). In Mediterranean ecosystems, acorn burial and consumption by some *Thorectes* species are important for acorn dispersal and *Quercus* forest regeneration (Pérez-Ramos et al., 2013; Verdú et al., 2007, 2011; Sánchez-Piñero et al., 2019).

Dung beetle populations play key roles in nutrient cycling, soil bioturbation, parasite control, plant growth and reduction of GHGs emissions. In this example, *Ateuchetus cicatricosus*, listed as Near Threatened, is a key species in the Doñana National Park, Spain. @ J.R. Verdú

1.3 Dung beetles in the Mediterranean region

Dung beetles are concentrated in the Mediterranean Basin and neighbouring areas in two main centres of endemism located at opposite ends of this region – the Maghreb–Iberian Peninsula area in the west and the Caucasus–Anatolia region in the east. This amphi-Mediterranean pattern of endemicity appears in Scarabaeinae and Aphodiinae (Lumaret & Lobo, 1996), but in the case of Geotrupinae endemicity is concentrated in the western Mediterranean, probably due to the ancient isolation of basal apterous lineages there (Cunha et al., 2011). The ancient evolutionary history of dung beetles together with the strategic location of the Mediterranean Basin at the crossroads of three continents, as well as the current mild and temperate climate of the region, are factors that have promoted the temporal juxtaposition of different dung beetle lineages (Lobo, 2007; Cabrero-Sañudo & Lobo, 2009). The contemporary diversity of dung beetles in the Mediterranean Basin is thus sustained by the region's role as both refugium and diversification centre. Therefore, the Mediterranean Basin harbours a diverse fauna of dung beetles from functional, evolutionary and ecological perspectives.

Mediterranean dung beetles are associated with open pastures and livestock rearing, probably because ancient human–nature interactions have reduced forest habitats and encouraged generalist, heliophilous dung beetle species (Martín-Piera & Lobo, 1996; Kadiri et al., 1997). However, the Mediterranean Basin also harbours a complex and diverse assemblage of dung beetles closely associated with the burrows and faeces of wild mammals such as rabbits (Sánchez-Piñero & Ávila, 1991; Verdú & Galante, 2004). As a result, Mediterranean dung beetles are especially important for the maintenance and management of moderately anthropised ecosystems and landscapes, so that any changes in farming practices are likely to have consequences for these species.

In the Mediterranean, there are about 644 dung beetle species (see Löbl & Löbl, 2016), 31% of which occur mainly within the region and around 23% are endemic, according to the criteria used to establish a species as Mediterranean (Table 1; see Box 3). The subfamily with the highest rate of endemism is Geotrupinae (Table 1).

Table 1. Total number of species of the three dung beetle subfamilies occurring within the Mediterranean region (S), number of species for which at least 75% of their distribution range is included within the Mediterranean region (S_{MED}), and number of species with their whole distribution range included in the Mediterranean region (S_{END})

Class	Order	Subfamily	S	S_{MED} (%)	S_{END} (%)
Insecta	Coleoptera	Geotrupinae	79	48 (60.8%)	37 (46.8%)
		Scarabaeinae	148	41 (27.7%)	27 (18.2%)
		Aphodiinae	417	111 (26.6%)	86 (20.6%)
		Total	644	200 (31.1%)	150 (23.3%)

1.4 Objectives of the regional assessment

Besides evaluating the extinction risk of dung beetles native to the Mediterranean region using the IUCN Red List Categories and Criteria, the main objectives of this regional assessment are:

- To contribute to regional conservation planning by providing a baseline dataset describing the conservation status of Mediterranean dung beetles;
- To identify geographical areas that need conservation measures to prevent extinctions and ensure that Mediterranean dung beetles reach and maintain a favourable conservation status;
- To develop a network of regional experts to enable species assessments to be continually updated as new information is discovered, and to provide expert opinion on policy and management recommendations.

The main outputs presented in this report are:

- A species list of the dung beetles that occur mainly in or are endemic to the Mediterranean region;
- An IUCN Red List categorisation of these species;
- A summary of the main threats affecting Mediterranean dung beetles;
- Recommendations for the future conservation of Mediterranean dung beetles and their habitats.

The data presented in this report provide a snapshot based on the knowledge existing at the time of this report. The database will be freely available and will continue to be updated on the IUCN Red List website (https://www.iucnredlist.org/). The IUCN will disseminate this information widely to decision makers, scientists and non-governmental organisations to mobilise conservation action for Mediterranean native dung beetles at the local, national and regional levels.

Traditional grazing on the Ifrane plateau (Morocco), a typical locality that hosts many dung beetles species including *Ateuchetus laticollis*, *Gymnopleurus sturmii*, *Onthophagus andalusicus* and *Thorectes armifrons.* © J.-P. Lumaret

Silphotrupes punctatissimus, an Endangered dung beetle species endemic to north-western Spain associated with *Quercus pyrenaica* forest and *Erica* thicket formations. © J.R. Verdú

2. Assessment methodology

2.1 The IUCN Red List of Threatened Species™

The IUCN Red List of Threatened Species™ (IUCN Red List) is widely recognised as the most comprehensive scientifically based source of information on the global conservation status of plant, fungi and animal species. IUCN Red List Categories and Criteria are applied to individual species assessments (which contain information on aspects such as ecology and life history, distribution, habitat preferences, threats, current population trends and conservation measures) to determine their relative threat of extinction. Taxa in categories Extinct EX and Extinct in the Wild EW correspond to taxa that have disappeared at global level or in their natural habitat respectively. Species in categories Critically Endangered CR, Endangered EN and Vulnerable VU are considered threatened. Taxa that either are close to meeting the threatened thresholds or would be threatened if it were not for ongoing conservation programmes are classified as Near Threatened NT. Taxa evaluated as having a relatively low risk of extinction are classified as Least Concern LC. Also highlighted within the IUCN Red List are taxa that cannot be evaluated due to insufficient knowledge, which are therefore assessed as Data Deficient DD. This category does not necessarily mean that the species is not threatened, only that its risk of extinction cannot be assessed from the currently available data (IUCN, 2017). Two additional categories are utilised for assessments at the regional level: Regionally Extinct RE, for taxa which have disappeared from the region being asssessed, and Not Applicable NA, for taxa deemed to be ineligible for assessment at a regional level because they do not have populations in the wild or within their natural range in the region, or because any individuals that occur in the region are vagrants from elsewhere (IUCN, 2012).

IUCN Red List assessments can be used as a tool for measuring and monitoring changes in the status of both biodiversity and our knowledge of the individual taxa. They provide an essential basis for setting targets for management priorities, and for monitoring the long-term success of management and conservation initiatives (IUCN, 2016).

2.2 The IUCN Red List Mediterranean assessment initiative

The extinction risk of a species can be assessed at a global, regional or national level. A species can have a different category in the Global Red List and in a regional Red List. For instance, a species which is common and distributed across a wide range and whose population has not declined enough to trigger criteria at global level can be listed as Least Concern LC in the Global Red List, but it could face a high level of threat and meet the criteria of a threatened category, for example Endangered EN, in a particular region. The guidelines for the application of IUCN Red List Criteria at regional level (IUCN Species Survival Commission, 2003) are applied to avoid any over- or underestimation of the regional extinction risk of a species. An endemic species should have the same category at both regional and global level, as it is not present in any other part of the world.

Therefore, this regional assessment for the Mediterranean region not only evaluates the conservation status of dung beetles at the regional level, but also contributes to their more comprehensive assessment at the global level.

Expert participants at the Mediterranean Dung Beetles Red List Workshop, July 2014, Doñana national Park, Spain. Left to right, front row: Ana Nieto, Alfonsina Arriaga, Violeta Barrios, Imen Labidi; back row: Francisco Cabrero, Catherine Numa, J. Luis Ruiz, Marco Dellacasa, Jean-Pierre Lumaret, José R. Verdú, Stefano Ziani, Yakup Şenyüz, Sinan Anlaş, Francisco Sánchez-Piñero. © IUCN-Med

2.3 Geographic scope

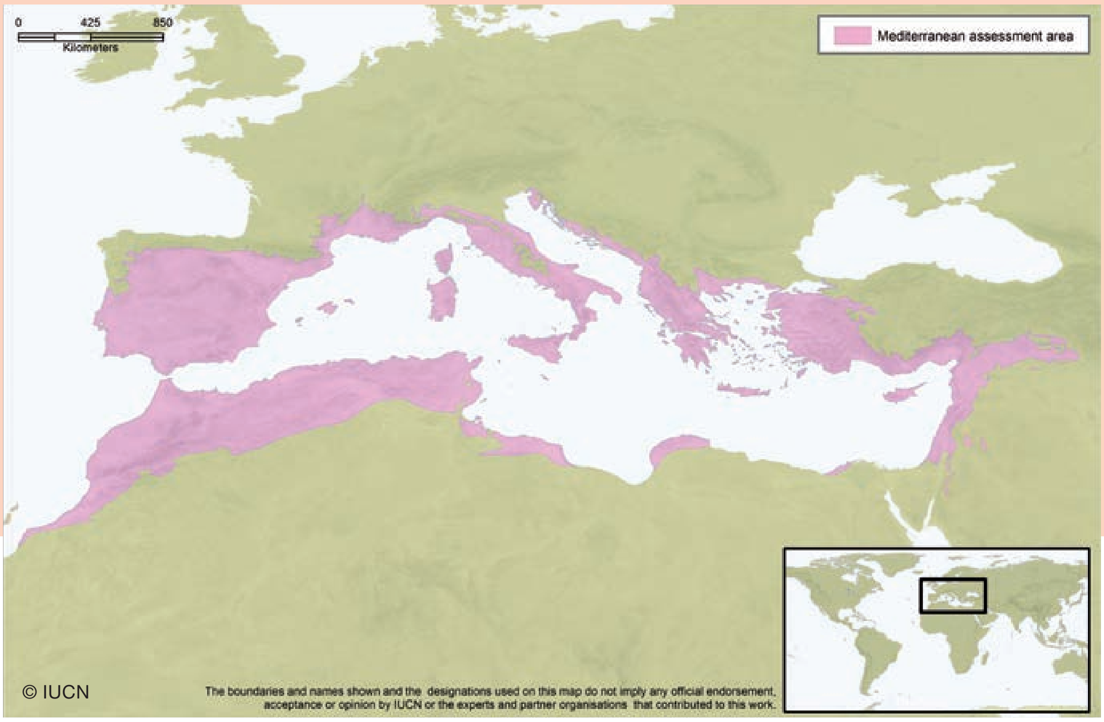
This assessment covers the Mediterranean region with the exception of the Macaronesian islands. However, it is not self-evident whether a particular species has a Mediterranean distribution or not. In the case of dung beetles, the target species selection procedure obeyed certain criteria to ensure its repeatability (Box 3).

BOX 3

DELIMITING MEDITERRANEAN SPECIES

The Mediterranean region was delimited according to both geographical and climatic criteria. First, all the dung beetle species inventories for countries bordering the Mediterranean Sea were selected from the Palaearctic catalogue by Löbl & Löbl (2016). The Köppen-Geiger climate classification proposed by Kottek et al. (2006; see http://koeppen-geiger.vu-wien.ac.at/) was then used to determine the regions with a Mediterranean-type climate (steppe climate and warm temperate climate with dry summer) within each of those countries. The resulting Mediterranean area (Figure 3) constituted our working region for selecting Mediterranean endemics and species occurring mainly within the Mediterranean region (excluding the subspecies level). For each of the 644 species thus selected, a convex-hull contour map of their total distribution was constructed using ModestR (García-Roselló et al., 2014; see www.ipez.es/modestr/). The area covered by each species within the Mediterranean region was then calculated in order to obtain its relative range size, which was used to determine target species. The criterion used was to include species having 75% or more of their total distribution range within this Mediterranean area (219 species). Lastly, experts reviewed the maps and species lists to produce a final consensus list of 200 species for assessment of their threatened status. These Mediterranean dung beetles include 150 species wholly distributed within the Mediterranean region as defined here.

Figure 3. The Mediterranean region as defined for this project.



2.4 Taxonomic scope

The taxonomic nomenclature for this assessment follows the IUCN Red List protocols, which, where possible, employ published taxonomic authorities as sources of information. The taxonomy mainly follows the Catalogue of Life (Schoolmeesters, 2015) and the Catalogue of Palaeartic Coleoptera (Löbl & Smetana, 2006; Löbl & Löbl, 2016). Infraspecific ranks are not considered, so subspecies are excluded even if they are distributed in the Mediterranean Basin. For more information on the taxonomic standards of the IUCN Red List, visit: https://www.iucnredlist.org/resources/tax-sources.

On the basis of these catalogues and the spatial analysis of the potential distribution maps for the species recorded in Mediterranean countries (Box 3), the regional assessment includes 200 native Mediterranean species. A checklist of these regionally assessed species is provided in Appendix 1. The taxonomic placement of species often changes because of new information from ongoing studies, especially with the introduction of molecular techniques (Scholtz et al., 2009).

2.5 Data collection, assessment and review

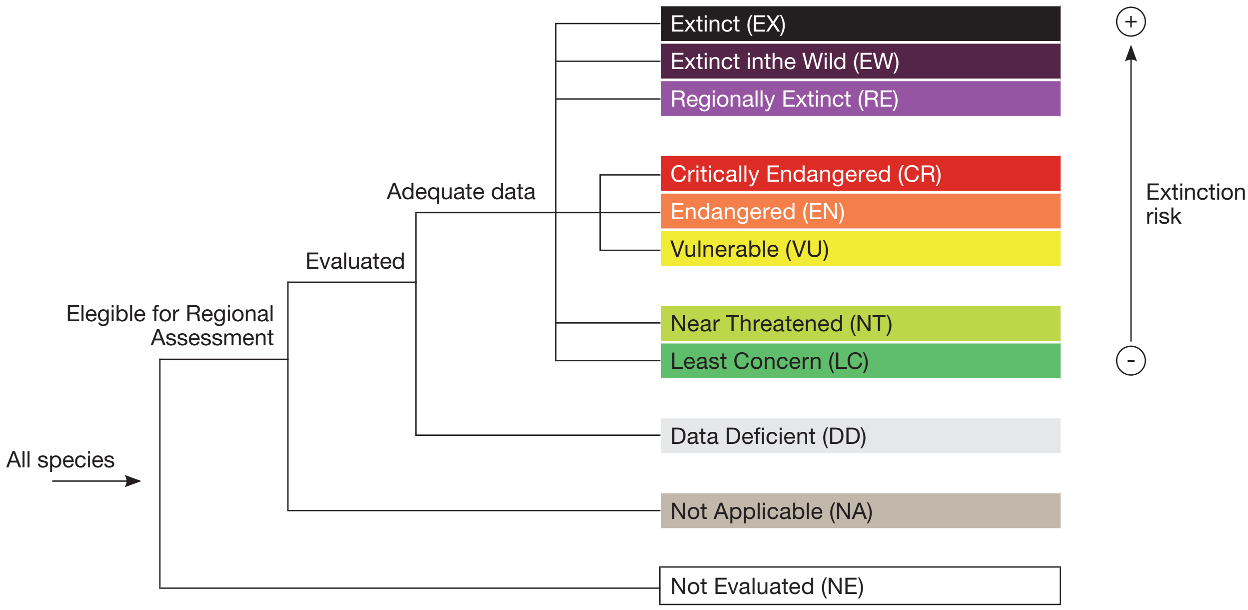
Information on habitat preferences and ecology, geographical distribution, threats, conservation measures, etc. was sourced and collated from bibliographical sources, expert observations and public databases for all the dung beetles endemic to or occurring mainly within the Mediterranean region (Box 3). Experts from across the region were identified through the Dung Beetle Conservation Network. All the relevant information available on each species was entered into the IUCN species database (Species Information Service – SIS). Spatial data was sourced for species distribution inferences by using an established method (Box 4), in which the extent of occurrence (EOO) of each species was obtained by applying a convex-hull contour map on the available observations, and the area of occupancy (AOO) was calculated after performing the process to estimate species distributions (see Box 4). ModestR and and ArcView GIS were used for the mapping process.

The species information was reviewed at a regional workshop held in the Doñana Biological Reserve, Spain, in July 2014. Each species assessment was jointly evaluated to ensure that the information presented was complete and correct and that the Red List category had been correctly applied according to the IUCN Red Listing procedures and documents, including the *Guidelines for Application of IUCN Red List Criteria at Regional Levels* (IUCN Species Survival Commission, 2003) and *IUCN Red List Categories and Criteria* (IUCN Species Survival Commission, 2001) (see Figure 4).

All the Mediterranean dung beetle assessments were finalised by July 2014. Experts from Mediterranean countries as well as from the IUCN SSC Terrestrial and Freshwater Invertebrates Specialist Group were then asked to review the species summary reports using a peer-review methodology. Their comments, together with any additional updated information, were included in the assessments.

Supported by relevant data sources and the scientific literature, these final regional assessments are therefore the outcome of information exchange and agreement among the numerous Mediterranean specialists involved and their networks of colleagues.

Figure 4. IUCN Red List Categories at the regional level (IUCN Species Survival Commission, 2003). For a description of each of the global IUCN Red List Categories, go to: www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria



2.6 Spatial analysis

Spatial data were gathered for the production of point distribution maps using Geocat, ModestR and ArcView GIS software. To that end, a database of georeferenced distributional information for 219 species belonging to the subfamilies Scarabaeinae (49 species and 13,727 database records), Aphodiinae (123 species and 7,409 records) and Geotrupinae (47 species and 2,796 records) was compiled. The participating experts provided this information and the point occurrence maps obtained were used to derive geographical representations aiming to reflect the probable distribution of each species (see Box 4). Species distribution maps were submitted to experts for validation and corrected where necessary.

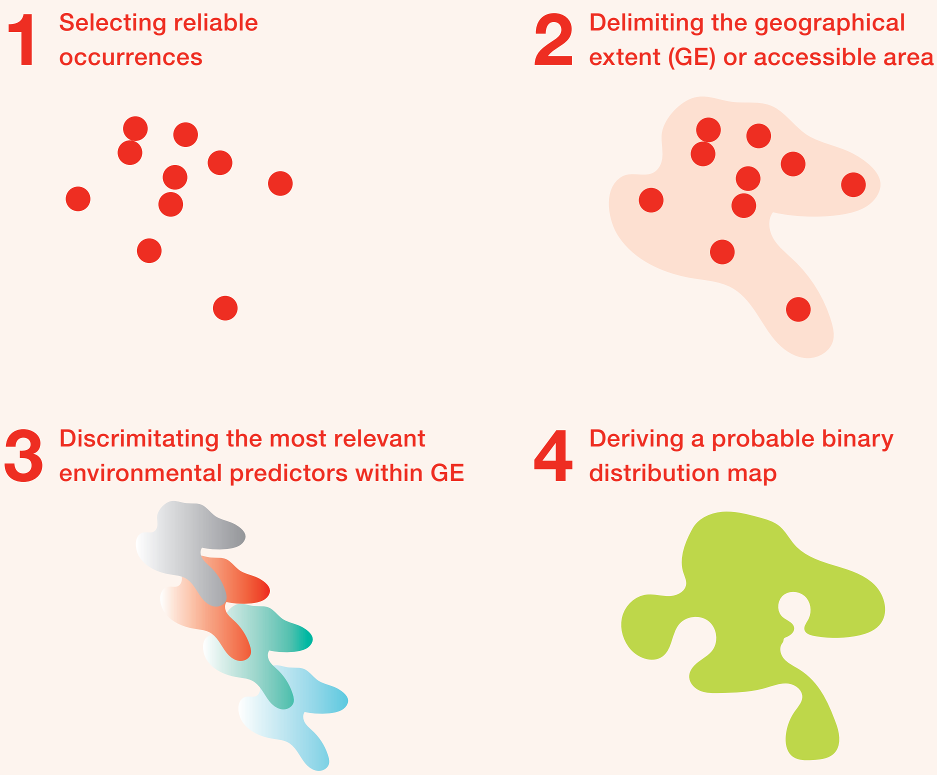
Final species distribution maps were produced and spatial analyses carried out using a geodesic discrete global grid system, defined on an icosahedron and projected onto the sphere using the inverse Icosahedral Snyder Equal Area (ISEA) projection. This corresponds to a hexagonal grid composed of individual units (cells) that retain their shape and area (~864 km^2 per cell in the Lambert Azimuthal Equal Area projection). These are more suitable for a range of ecological applications than the more commonly used rectangular grids (see Kimmerling et al., 1999). The estimated range of each species was converted to the hexagonal grid for analysis purposes. Coastal cells were clipped to the coastline. Patterns of species richness were mapped by counting the number of species in each cell (or cell section for species with a coastal distribution). Patterns of threatened species richness were mapped by counting the number of threatened species (categories CR, EN, VU at the Mediterranean regional level) in each cell or cell section. Patterns of endemic species richness were mapped by counting the number of species in each cell (or cell section for coastal species) that were flagged as being endemic to the Mediterranean region as defined in this project. Patterns of Data Deficient species richness were mapped by counting the number of species in each cell (or cell section for coastal species) that were flagged as being listed as Data Deficient at the Mediterranean level.

BOX 4

ESTIMATING SPECIES DISTRIBUTIONS

The procedure used to infer the probable realised distribution of each dung beetle species from the georeferenced available data is based on a recently proposed method (niche of occurrence or NOO; see García-Roselló et al., 2019; Figure 5, below). This simple modelling procedure avoids the use of so-called background absences and complex modelling techniques. NOO produces a geographical representation of climatically suitable areas that have environmental conditions similar to those in localities with observed occurrences and which are also accessible by the species (i.e. the climatically suitable area contained within an imaginary boundary delimited by the observed occurrences). The range of each species was firstly delimited by applying a convex-hull contour map to the available points of occurrence in order to estimate the extent of occurrence (EOO). This EOO is considered the most probable area that is accessible by each species. A value of the Variance Inflation Factor lower than 30 was then used to eliminate sequentially some of the predictors used, retaining those that were less correlated with each other. These predictors were subsequently analysed to select the variables most able to discriminate the occurrence cells in the selected EOO region (Guisande et al., 2017). All these steps were followed individually for each species. The variables used in this case are the 19 freely available WorldClim bioclimatic variables (see www.worldclim.org; Hijmans et al., 2005). The maximum and minimum values of the selected variables in the occurrence cells were used to derive a probable binary distribution map (suitable and unsuitable cells) in an attempt to represent accessible areas with similar climatic conditions to those existing at the observed points of occurrence. The complete process was carried out at 1-minute resolution (0.0167 decimal degrees; a cell of approximately 4 km^2, which is the resolution used to calculate AOO for the IUCN Red List).

Figure 5. Main steps in inferring the probable distribution of species by the NOO method (García-Roselló et al., 2019)



Forest of *Quercus pyrenaica* and *Castanea sativa* in El Castañar de El Tiemblo (central Spain), the preferable habitat for some threatened dung beetles such as *Ceratophyus martinezi*. © J.R. Verdú

3. Assessment results

3.1 Conservation status of Mediterranean dung beetles

Of the 644 dung beetle species recognised as occurring in the Mediterranean region, the thorough expert review determined that 200 can be considered typically Mediterranean and 150 of these are endemic to the region (see Box 4). A complete list of the dung beetle species included in this project together with their IUCN Mediterranean Red List status is provided in Appendix 1. The numbers and proportions of species in the various Red List Categories are presented in Table 2.

Twenty-five species were found to be threatened with extinction (CR, EN or VU) in the Mediterranean region, 21 of them endemics. An additional 14 species are listed as Near Threatened (8 endemics), 74 species as Data Deficient (57 endemics) and 87 species as Least Concern (64 endemics).

Table 2. Summary of the Red List status of Mediterranean dung beetles (Smed) and dung beetles endemic to the Mediterranean region (Send). Threatened categories are highlighted in colour and the percentage in each category is given in parentheses.

IUCN Red List Categories	SMED (%)	SEND (%)
Extinct	0	0
Regionally Extinct (RE)	0	0
Critically Endangered (CR)	1 (0.5%)	1 (0.7%)
Endangered (EN)	21 (10.5%)	17 (11.3%)
Vulnerable (VU)	3 (1.5%)	3 (2.0%)
Near Threatened (NT)	14 (7.0%)	8 (5.3%)
Least Concern (LC)	87 (43.5%)	57 (38.0%)
Data Deficient (DD)	74 (37.0%)	64 (42.7%)
Total number of species assessed	**200**	**150**

3.2. Threatened species CR EN VU

The percentage of threatened dung beetle species (CR+EN+VU categories) is 12.5%, but this must be considered a lower-bound value which depends on the real status of the species classified as Data Deficient (DD). If all DD species turned out to be threatened (CR+EN+VU+DD), we would obtain an upper bound percentage of 49.5% threatened, while if these DD species were excluded from the total number of assessed species we would obtain a mid-point percentage of 19.8% (IUCN, 2011; Table 3, below). This mid-point value is considered the best estimate of the proportion of threatened species (IUCN, 2011).

Of the 150 dung beetle species that are endemic to the Mediterranean region (i.e. their whole distribution lies within the Mediterranean region), 21 are threatened with extinction, which is equivalent to a mid-point estimate of 24.4%.

Table 3. Percentages of typically Mediterranean dung beetle species (TMS) and of endemic Mediterranean dung beetle species (EMS) that are threatened.

	%TMS	%EMS
Lower bound (CR+EN+VU) / (assessed – EX)	12.5	14.0
Mid-point (CR+EN+VU) / (assessed – EX – DD)	19.8	24.4
Upper bound (CR+EN+VU+DD) / (assessed – EX)	49.5	56.7

Although the assessment was not exhaustive enough to cover the entire dung beetle fauna in the region, it shows that, in comparison with other groups of terrestrial fauna in the region, dung beetles include a high proportion of threatened species: less than saproxylic beetles (32%), amphibians (30%) and reptiles (23%); similar to mammals (18%); but higher than birds (6%) and butterflies (5%) (Numa et al., 2016; Critical Ecosystem Partnership Fund, 2017).

The only species listed as Critically Endangered, the highest category of threat, is *Thorectes coloni* Ruiz 1988. This species is endemic to Morocco and is known from only four localities (EOO = 455.5 km^2; AOO = 143.8 km^2). It is restricted to karstic areas with limestone soils and open Mediterranean scrublands. Limestone quarries in its distribution range, together with a decline in sheep farming, are the main threats to this species. Seventeen endemic species are considered Endangered and three species are listed as Vulnerable (Table 2). The percentage of Data Deficient endemic species is 42.7%, which indicates that endemic species in the Mediterranean region are generally not very well known or studied.

Twenty-one Mediterranean species are listed as Endangered (Table 4). The area with the highest number is the Iberian Peninsula, where 12 Endangered species occur. These species are affected in general by the indiscriminate use of veterinary medical products, which have deleterious effects on the fauna associated with livestock faeces. *Chelotrupes momus* (Olivier, 1789), *Jekelius hispanus* (Reitter, 1892), *Jekelius puctatolineatus* (François, 1904) and *Heptaulacus gadetinus* Baraud, 1973 are Endangered endemic species inhabiting coastal areas of the Iberian Peninsula. These species are mainly affected by urbanisation and tourism infrastructure development; livestock abandonment and the decline of rabbit populations make their conservation status worse. Three additional species located in mountainous areas of Spain (*Jekelius catalonicus* (López-Colón, 1991), *Silphotrupes punctatissimus* (Chevrolat, 1840) and *Jekelius balearicus* (López-Colón, 1985)) are also listed as Endangered, due to the negative effects of grazing abandonment, urbanisation and road infrastructure. The Endangered species living in forested areas, *Thorectes baraudi* López-Colón, 1981, *Jekelius castillanus* (López-Colón, 1985) and *Ceratophyus martinezi* Lauffer, 1909 are affected by habitat degradation due to forest and scrub clearing and grazing abandonment.

Table 4. Dung beetle species listed as threatened at the Mediterranean regional level.

Family	Subfamily	Species	Author	RL status
Geotrupidae	Geotrupinae	*Thorectes coloni*	Ruiz, 1998	CR
Geotrupidae	Geotrupinae	*Ceratophyus martinezi*	Lauffer, 1909	EN
Geotrupidae	Geotrupinae	*Ceratophyus rossii*	Jekel, 1866	EN
Geotrupidae	Geotrupinae	*Chelotrupes hiostius*	(Gené, 1836)	EN
Geotrupidae	Geotrupinae	*Chelotrupes momus*	(Olivier, 1789)	EN
Geotrupidae	Geotrupinae	*Jekelius balearicus*	(López-Colón, 1985)	EN
Geotrupidae	Geotrupinae	*Jekelius castillanus*	(López-Colón, 1985)	EN
Geotrupidae	Geotrupinae	*Jekelius catalonicus*	(López-Colón, 1991)	EN
Geotrupidae	Geotrupinae	*Jekelius chersinus*	(Delabie, 1954)	EN
Geotrupidae	Geotrupinae	*Jekelius hernandezi*	(López-Colón, 1988)	EN
Geotrupidae	Geotrupinae	*Jekelius hispanus*	(Reitter, 1892)	EN
Geotrupidae	Geotrupinae	*Jekelius punctatolineatus*	(François, 1904)	EN
Geotrupidae	Geotrupinae	*Jekelius sardous*	(Erichson, 1847)	EN
Geotrupidae	Geotrupinae	*Renaudtrupes distinctus*	(Marseul, 1878)	EN
Geotrupidae	Geotrupinae	*Silphotrupes punctatissimus*	(Chevrolat, 1840)	EN
Geotrupidae	Geotrupinae	*Thorectes baraudi*	López-Colón, 1981	EN
Geotrupidae	Geotrupinae	*Thorectes coiffaiti*	Baraud, 1969	EN
Geotrupidae	Geotrupinae	*Thorectes puncticollis*	Lucas, 1846	EN
Geotrupidae	Geotrupinae	*Thorectes variolipennis*	Marseul, 1876	EN
Scarabaeidae	Aphodiinae	*Ahermodontus ambrosi*	(Pardo Alcaide, 1936)	EN
Scarabaeidae	Aphodiinae	*Heptaulacus gadetinus*	Baraud, 1973	EN
Scarabaeidae	Aphodiinae	*Nimbus anyerae*	(Ruiz, 1998)	EN
Geotrupidae	Geotrupinae	*Thorectes valencianus*	(Baraud, 1966)	VU
Scarabaeidae	Scarabaeinae	*Ateuchetus semipunctatus*	(Fabricius, 1792)	VU
Scarabaeidae	Scarabaeinae	*Onthophagus albarracinus*	Baraud, 1979	VU

Jekelius hernandezi (López-Colón, 1988), endemic to the south-eastern Iberian Peninsula, and *Jekelius chersinus* (Delabie, 1954), a species confined to the eastern part of the French Pyrenees, inhabit open Mediterranean scrublands and forests of *Quercus rotundifolia*. These species are threatened by the abandonment of traditional farming activities, the spread of vineyards, the decline of rabbit populations, the increase in road infrastructure and the urbanisation of coastal areas.

Two species from Mediterranean islands, mainly inhabiting coastal dunes, are also listed as Endangered: *Jekelius sardous* (Erichson, 1847), a Sardo-Corsican endemic species, and *Chelotrupes hiostius* (Gené, 1836), endemic to Sardinia. The main threats to these species are habitat loss and degradation due to tourism infrastructure development. Moreover, the abandonment of traditional livestock production in favour of an intensification of practices could worsen the conservation status of these species.

Similarly, *Ceratophyus rossii* Jekel, 1856, a species restricted to a small area of sandy coastal land in Tuscany (Italy), is also affected by habitat loss, degradation and fragmentation resulting from the abandonment or reduction of extensive grazing, and increased veterinary residues in livestock faeces.

Six of the 21 species listed as Endangered occur in northern Africa. Most of them are affected by changes in land use, intensification of agriculture and increased urbanisation in coastal areas. That is the case for *Ahermodontus ambrosi* (Pardo Alcaide, 1936), a species known from north-eastern Morocco and the Spanish North African territory of Melilla; *Thorectes coiffaiti* (Baraud, 1969) and *Thorectes variolipennis* (Marseul, 1876), both from coastal areas of Morocco; *Thorectes puncticollis* Lucas, 1845, from coastal areas of Algeria, Tunisia and Libya; and *Renaudtrupes distinctus* (Marseul, 1878), a species from forested coastal areas of the Maghreb region.

The small *Nimbus anyerae* (Ruiz, 1998) is another Endangered species restricted to north-western Morocco. This species inhabits Mediterranean scrublands and small meadows on calcareous soils and is affected by limestone quarries, changes in land use and agro-pastoral farming systems.

Three species are listed as Vulnerable. All of them are affected by the residues of veterinary products in livestock faeces. *Thorectes valencianus* (Baraud, 1966), an endemic species inhabiting Mediterranean scrublands in south-eastern Spain, is affected by intentional fires, urbanisation, scrubland clearing for intensive agriculture and livestock abandonment. *Onthophagus albarracinus* Baraud, 1979, a Spanish endemic species, is also threatened by the abandonment of traditional grazing practices, while the large-bodied roller species *Ateuchetus semipunctatus* (Fabricius, 1792) inhabiting coastal dunes suffers from habitat loss and degradation caused by intensive urbanisation and infrastructure development throughout its entire Mediterranean-wide distribution, and the former use of particularly dangerous veterinary medicinal products (organophosphates).

Ateuchetus semipunctatus, a roller dung beetle that inhabits the coastal dunes of the western Mediterranean. Listed as Vulnerable. © J.R. Verdú

3.3 Near Threatened species NT

Overall, 14 species (7%) were assessed as Near Threatened, reflecting concern that they are close to qualifying for a threatened category and could do so in the near future. It is essential that these species be closely monitored and, where possible, management action should be taken to prevent them from being listed as threatened in the future. Eight of the 14 Near Threatened species are endemic to the Mediterranean region (Table 2).

Again, the presence of residues of veterinary products in faeces is affecting all these species. The highest numbers of Near Threatened species occur in the Iberian Peninsula and Morocco. *Onthophagus merdarius* Chevrolat, 1865, *Thorectes lusitanicus* (Jekel, 1866), *Ammoecius lusitanicus* (Erichson, 1848), *Jekelius albarracinus* (Wagner, 1928) and *Ceratophyus hoffmannseggi* (Fairmaire, 1856) are susceptible to grazing abandonment, urbanisation and the decline of rabbit populations. *Ateuchetus cicatricosus* (Lucas, 1856), *Euorodalus boiteli* (Théry, 1918) and *Heptaulacus brancoi* Baraud, 1976 are present in the western part of the Mediterranean Basin and are threatened by the anthropisation of coastal areas and changes in land use, such as abandonment of traditional extensive grazing, exotic plantations and intensification of agriculture. *Alocoderus carinifrons* (Reitter, 1892) and *Anomius peyerimhoffi* (Théry, 1925) are endemic to Morocco and suffer from increased urbanisation and exotic forest plantations. *Jekelius marginatus* (Poiret, 1787) is distributed in Sicily and the Maghreb region, and is particularly threatened in Sicily by habitat loss due to coastal anthropisation and grazing abandonment or prohibition. Moreover, its coastal distribution makes this species sensitive to climate change and subsequent sea-level rise. *Anomius crovettii* (G. Dellacasa, 1983) is endemic to south-western Sardinia, where the development of tourism infrastructure, the abandonment of extensive livestock farming and intensification are the major threats to this species. *Gymnopleurus sturmii* (MacLeay, 1821) is a widely distributed species throughout the Mediterranean Basin. Changes in land use, livestock abandonment and intensification are the major threats affecting this species. Finally, the phytophagous species *Lethrus fallax* Nikolajev, 1975 occurs in Greece, Turkey and Bulgaria and is affected by urbanisation and agriculture intensification and the associated heavy application of pesticides.

Onthophagus albarracinus is endemic to the Iberian System in Spain. Listed as Vulnerable. © J.R. Verdú

3.4 Data Deficient species DD

The gaps in our knowledge about Mediterranean dung beetles are particularly evident when the numbers and proportions of species listed as Data Deficient (DD) are considered. This indicates that there is not enough information available for an accurate assessment of their extinction risk. Scarcity of data is often due to a lack of research, or to the fact that species are (or have become) rare, or have an unknown or poorly known geographical distribution. Seventy-four (37%) of the dung beetle species assessed are listed as DD (Table 2). This is equivalent to 12% of the total number of species estimated to occur in the region and highlights the need for continued targeted research on these species.

It is highly probable that some of these Data Deficient species are threatened by anthropogenic pressures. Research efforts focusing on species for which there is currently little knowledge must therefore be urgently increased, because Data Deficient listing does not mean that these species are not threatened. In fact, as knowledge improves, such species are sometimes found to be among the most threatened (IUCN, 2016). It is therefore essential to direct research efforts and funding towards these species, as well as those in the threatened categories. This is particularly important where there are apparent threats but no available data on population sizes or biological parameters.

There are some species for which additional studies are necessary because their current taxonomic status may change once new molecular and morphological studies are completed. This might happen to *Thorectes trituberculatus* (Reitter, 1892), *Onthophagus massai* Baraud, 1975, *Onthophagus circulator* Reitter, 1891, or *Alocoderus mineti* (Clément, 1981). Similarly, better distributional data are needed for those recently split taxa recognised as sibling species. This is the case of *Onthophagus vacca* (Linnaeus, 1767) and *O. medius* (Kugelann, 1792), and also *Aphodius fimetarius* (Linnaeus, 1758) and *A. pedellus* (De Geer, 1774).

3.5 Least Concern species LC

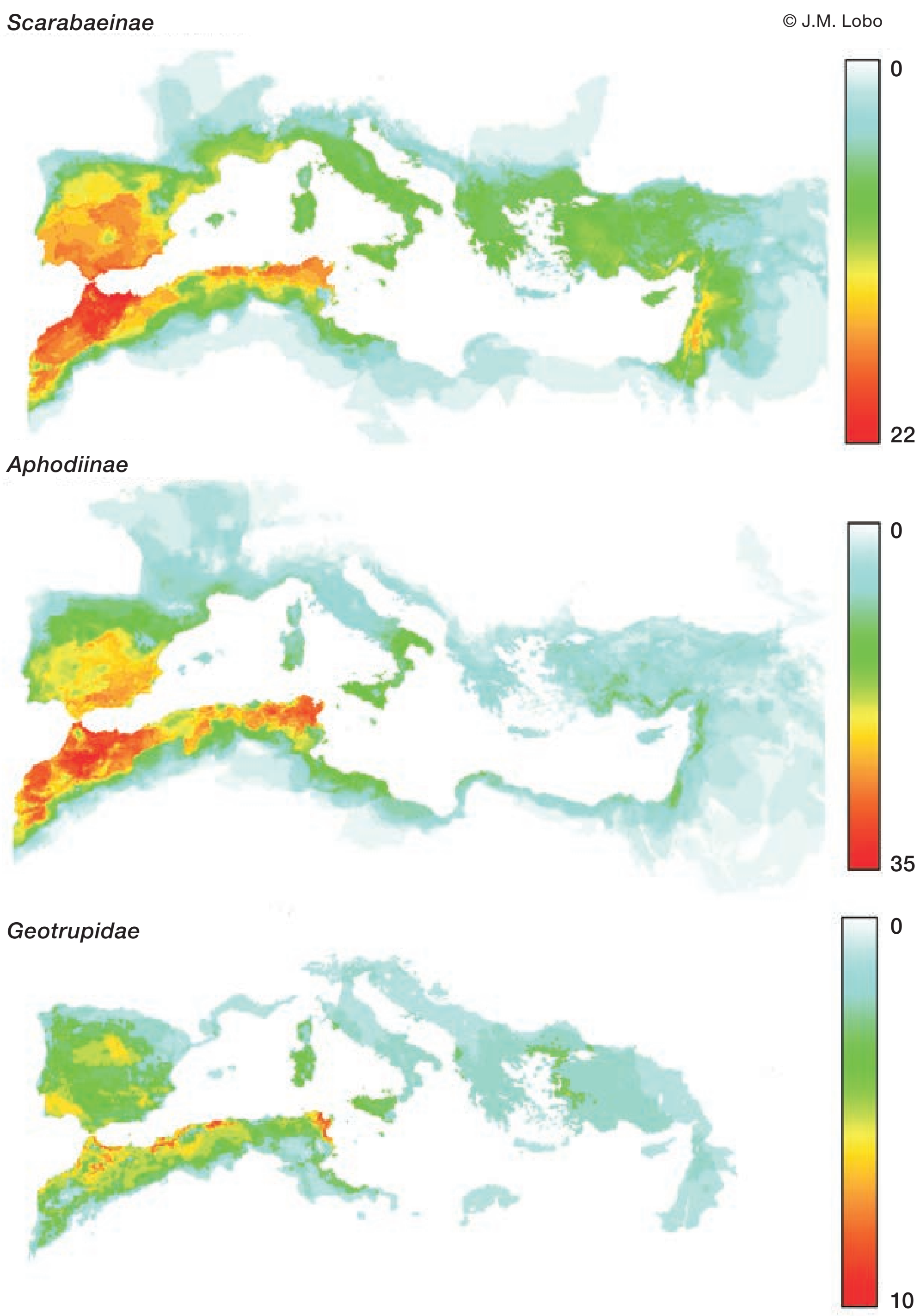
In the Mediterranean region, almost half of the dung beetle species (43.5%, 87 species) are listed as Least Concern (Table 2). They are not considered to be under any known major threat of extinction now or in the near future. Many of these species are generally abundant and/or relatively widespread and, as a consequence, resilient to the threats and pressures mentioned in this assessment. Some of these species may still benefit from conservation management actions, even though they are listed as Least Concern.

Renaudtrupes distinctus inhabits cork-oak forests on sandy soils in northern Morocco. Listed as Endangered. J.L. Ruiz

3.6 Spatial distribution of species

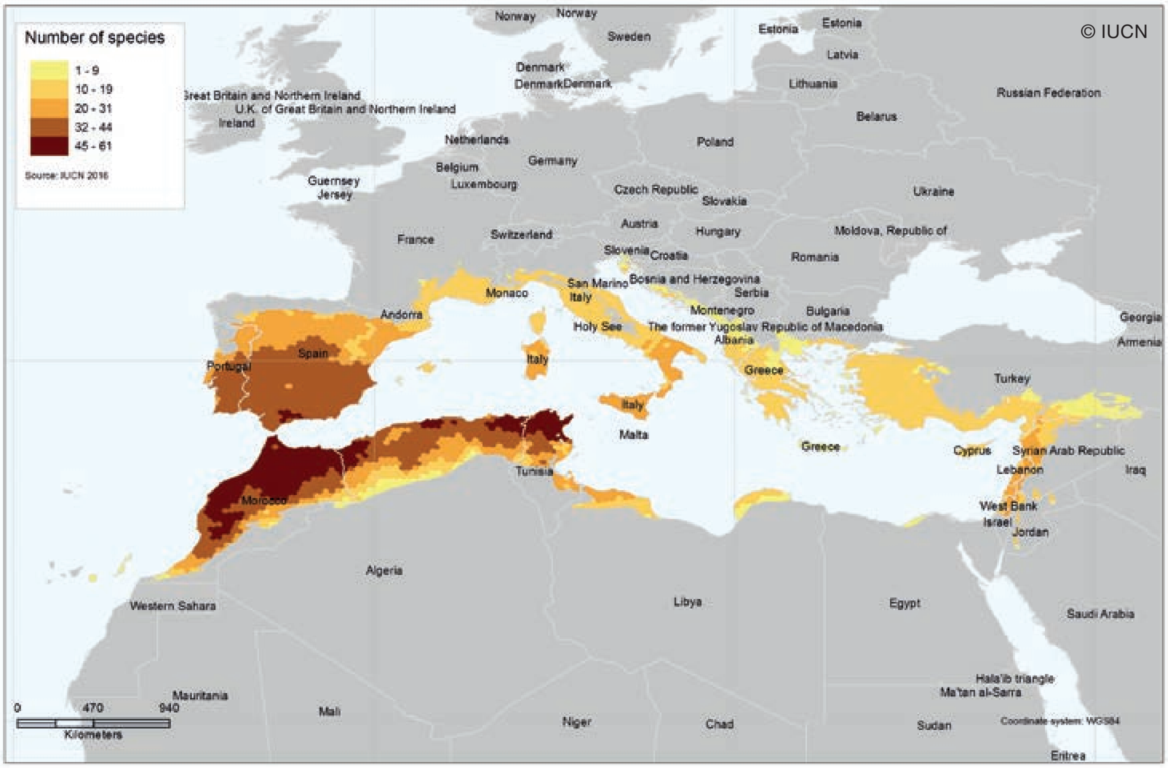
The Mediterranean dung beetles assessed show a non-homogeneous geographical distribution, depending on the dung beetle subfamily considered (Figure 6). In Scarabaeinae, species richness shows a clear amphi-Mediterranean pattern, in which the highest number of species appears in the western Mediterranean region. However, in Aphodiinae and Geotrupinae most species seem to be limited to the southern part of the Iberian Peninsula and especially north-western Africa (from Tangier to Safi, through the Rif Mountains and the Middle Atlas, in the surroundings of Algiers and north-western Algeria and in northern Tunisia).

Figure 6. Geographic variation in species richness in the Mediterranean region for each of the three subfamilies of dung beetles



The general distribution of endemic dung beetle species (n = 150) is similar, with most of the endemic species concentrated in the Maghreb and the southern Iberian Peninsula. Again, the highest values of endemicity are found in Morocco, especially in the Atlantic coastal habitats from Tangier to Safi, the Rif Mountains, the Middle Atlas and the coastal habitats of Algeria and Tunisia. Important areas of dung beetle endemism are also the southern edge of the Iberian Peninsula in Spain and Portugal and the northern part of Sicily, Italy (Figure 7).

Figure 7. Geographic variation in the species richness of endemic dung beetles in the Mediterranean region



Threatened dung beetles (n = 25) are concentrated in the coastal habitats of the southern and eastern Iberian Peninsula, in Sardinia, and along the Atlantic and Mediterranean coasts of North Africa from Morocco to Tunisia (Figure 8). Other important areas are located in the inland mountains of the south-eastern Iberian Peninsula.

The geographical distribution of Data Deficient species reveals the areas where further studies on dung beetle distribution, population size, trends and conservation status are needed (Figure 9). Northern Africa, Mediterranean Turkey and the Levant are where most Data Deficient dung beetles are concentrated.

Figure 8. Geographical distribution of threatened dung beetle species (VU, EN, CR) in the Mediterranean region

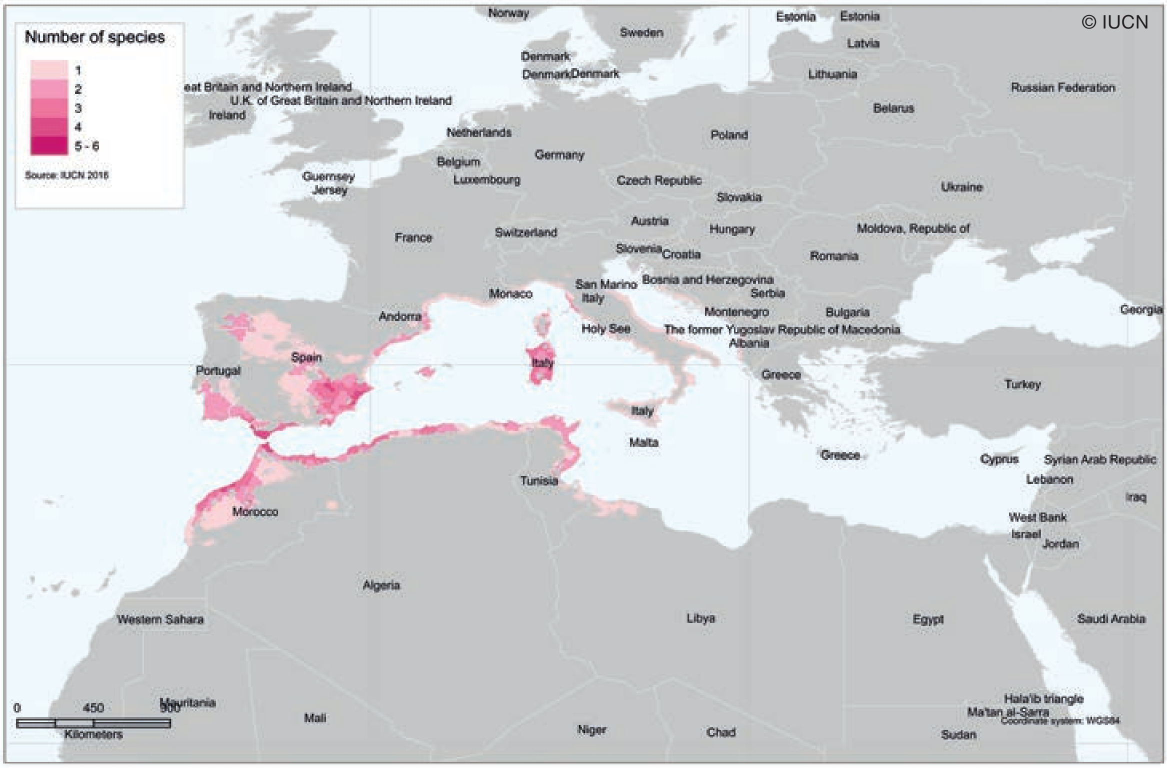
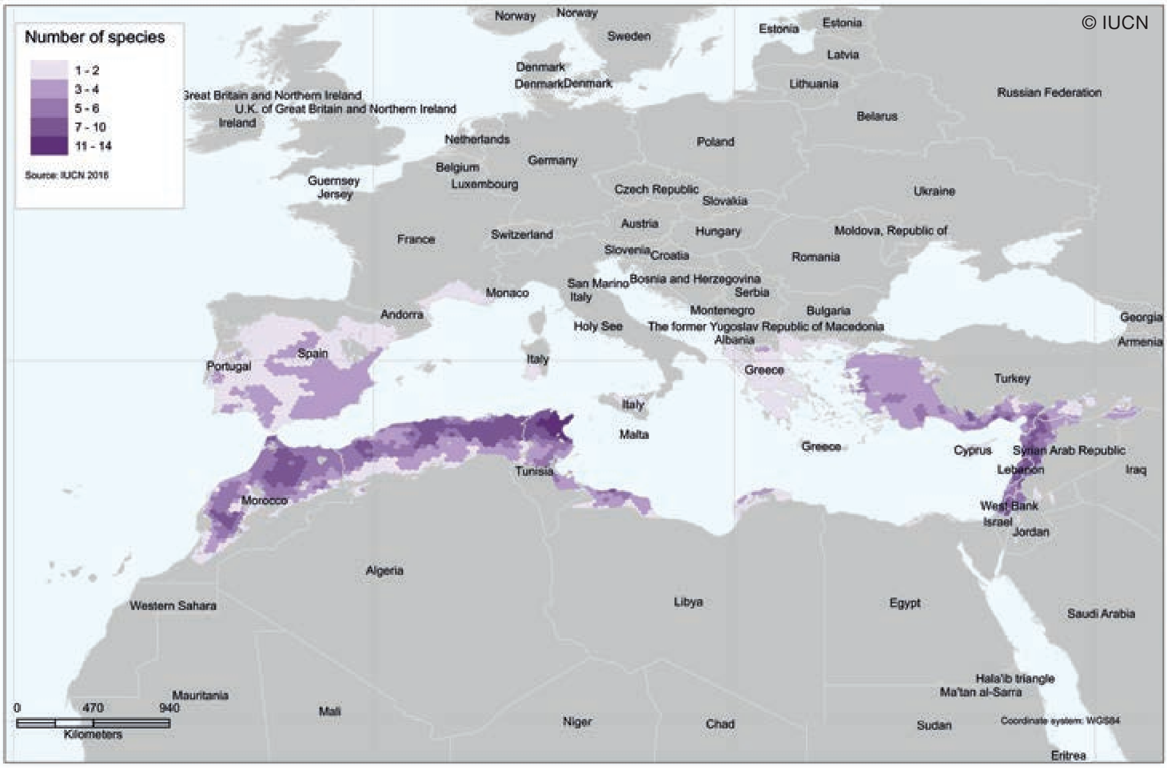


Figure 9. Geographical distribution of dung beetle species listed as Data Deficient in the Mediterranean region



3.7 Major threats to dung beetles in the Mediterranean region

A summary of the major threats to dung beetles in the Mediterranean region, according to the IUCN Threat Classification Scheme, is presented in Figure 10 for both threatened (25) and non-threatened taxa (175).

Human modification of natural ecosystems, pollution, residential and commercial development and agriculture management constitute the most important threats to both threatened and non-threatened taxa. Alterations to natural ecosystems and traditional farming practices, including livestock management, range from the abandonment of extensive and semi-extensive grazing systems to the intensification of industrial agriculture and intensive/industrial livestock production systems. Habitat degradation often ensues due to shrub encroachment and grassland loss. Overgrazing, which compacts the soil through trampling and changes vegetation structure and landscape organisation, is one of the main threats to dung beetles in some regions of the Mediterranean, such as parts of the Middle Atlas Mountains of Morocco. Conversely, livestock abandonment leads to a reduction in the quantity of trophic resources (dung) and landscape transformation. In the arid Guadix-Baza Basin (SE Spain), for example, the abandonment of extensive livestock grazing has led to a drastic reduction in dung beetle abundance, resulting in species becoming rarer and probably leading to local population extinctions, as well as profound changes in assemblage composition (Sánchez-Piñero et al., unpublished data) (see Box 5).

The comprehensive use of veterinary medical products leads to contamination of livestock faeces. The majority of these substances are poorly metabolised by livestock and are voided unaltered in their faeces, causing a great impact on non-target fauna such as dung beetles. The detrimental effects of these chemical products can be observed in the Euro-Mediterranean region, where the routine use of these products is adversely affecting the populations of all dung beetles, especially those of larger body size with low population recruitment rates (see Box 6).

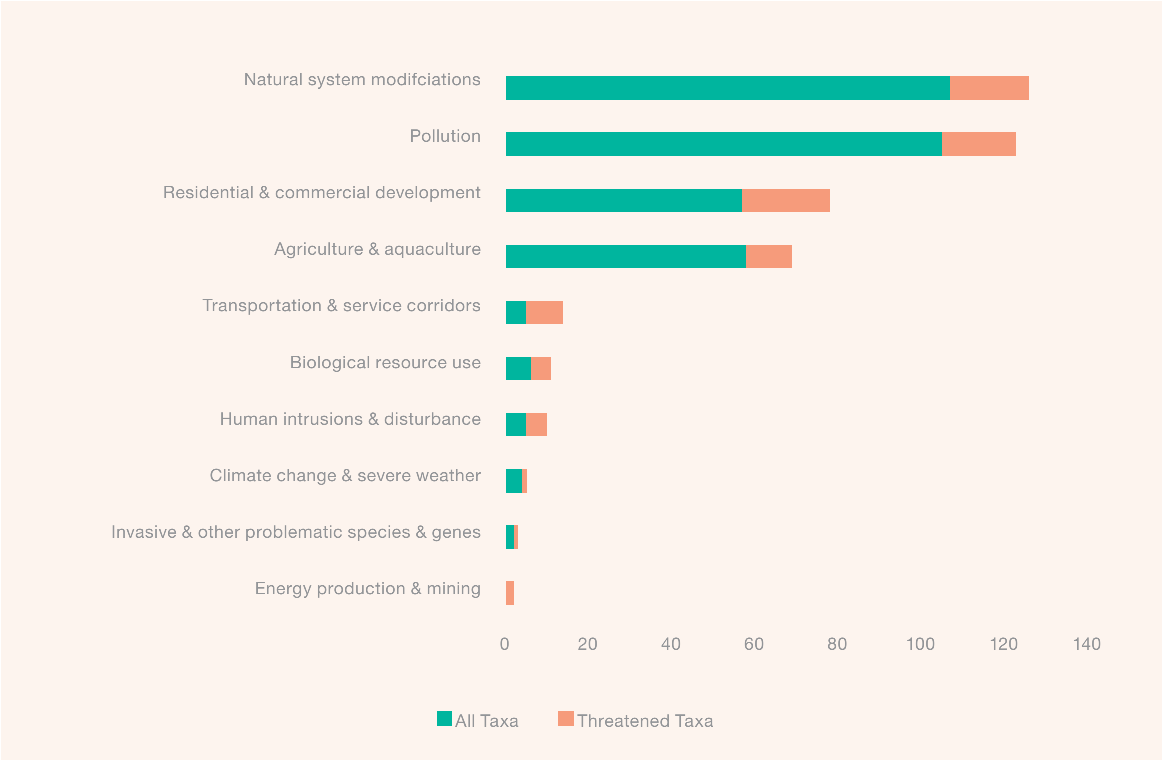
Residential and commercial development involves the expansion of urbanisation and tourism infrastructure. These threats mainly affect coastal areas, where land is in great demand for infrastructure development. Transportation and service corridors are also important drivers of habitat fragmentation, especially for flightless species (genera *Ahermodontus, Baraudia, Jekelius, Lethrus, Renaudtrupes, Thorectes* and some *Chelotrupes* species). These species have a reduced dispersal ability and any infrastructure that prevents individual movements increases the fragmentation of their populations.

Biological resource use mainly involves the trapping of individuals for sale to collectors. Although this activity is a rather negligible threat and seems to involve a minority of species, it could become an issue as more species become rarer.

Climate change does not appear to be a major threat at present. However, it is possible that some coastal and mountain species may be adversely affected by future sea-level rise and upward isotherm displacements. For example, *Silphotrupes punctatissimus*, an endemic species of the Astur-Galaica subprovince (Spain), may suffer the effect of future climate change due to its mountain affinities. *Chelotrupes hiostius*, an endemic from Sardinia, is a coastal dune species that may be affected by future flooding and erosion due to sea-level rise. This is also the case for the coastal species *Ateuchetus semipunctatus*. In any case, the synergistic effects of climate change and land use changes could seriously affect dung beetles in the near future, as anthropic pressures on mountain and temperate areas increase.

The population decline of the rabbit (*Oryctolagus cuniculus*), an ecoystem engineer species, may also seriously affect some native dung beetles closely adapted to consuming its faeces. Disease epidemics in lagomorphs resulting in high mortality may seriously jeopardise the survival of these dung beetle species.

Figure 10. Summary of threats to 200 native dung beetle species assessed in the Mediterranean region.



A quarry in the Haus mountain range has important impacts on the habitat of *Thorectes coloni*, an apterous species endemic to the north of Morocco and listed as Critically Endangered © J.L Ruiz

BOX 5

IMPACT OF GRAZING ABANDONMENT AND LIVESTOCK INTENSIFICATION ON DUNG BEETLE BIODIVERSITY

In areas with a long history of human management, where habitat heterogeneity and biodiversity have been shaped and maintained by agro-pastoral activities, the abandonment of traditional agricultural and livestock management practices is an important threat to biodiversity (Rey-Benayas et al., 2007; Stoate et al., 2009). Livestock has long been a key factor in landscape structure and ecosystem functioning in the Mediterranean basin (Perevolotsky & Seligman, 1998; Blondel et al., 2010; Zeder, 2008; Diacon-Bolli et al., 2012). However, in the last 50–60 years, higher consumption due to population growth and rising incomes, as well as the adoption of new production techniques and marketing channels, have changed livestock production systems globally (FAO, 2009; Pingali & McCullough, 2010; Thornton, 2010).

In the Mediterranean region, livestock grazing remains an important economic activity (Bernués et al., 2011; van de Steeg & Tibbo, 2012). However, livestock farming systems are changing in different ways around the Mediterranean Basin. In most North African and Middle Eastern countries, where large areas of arid and semi-arid land are used for extensive grazing, one of the effects of increased demand has been intensification, achieved primarily by providing supplemental feed (mainly imported grain) (Zaroug & Mirreh, 2010; Sraïri, 2015; El Aich, 2018). It also involves sedentarisation and overgrazing (Boulanouar & Paquay, 1994; Zaroug & Mirreh, 2010; Sraïri, 2015; El Aich, 2018), resulting in increased degradation (erosion, soil compaction, etc.) of the grazed areas (Boulanouar & Paquay, 1994).

In the European Mediterranean countries there have been two opposite trends: intensification, with a larger number of animals per farm and a shift to industrial production systems, and the abandonment of extensive grazing in marginal areas such as mountain and dryland regions (Baldock et al., 1996; Reid et al., 2010; Bernués et al., 2011; Sturaro et al., 2012). For example, in marginal areas of Spain extensive sheep and goat grazing has been drastically replaced with more profitable intensive industrial holdings (Castel et al., 2011; Toro-Mujica et al., 2015). A similar pattern has occurred in northern Italy, where livestock grazing has been abandoned in some areas, whereas other areas have been overgrazed (ISTAT, 2010; Sturaro et al., 2012).

An additional change in livestock management associated with intensification is specialisation. The number of mixed cattle and sheep or goat farms, which were still common in the 1990s, has fallen sharply, so a process of specialising in a single species has occurred in parallel with the consolidation and increasing size of holdings (Bernués et al., 2011). As a result, the numbers of farms and grazing stock reported across the European Mediterranean countries fell drastically in the first few years of the 21st century (2000–2007), with holdings showing more animals per farm, more specialisation in the species farmed and a net increase in industrial livestock (Thornton, 2010; Reid et al., 2010; Bernués et al., 2011).

These changes in livestock systems have profound impacts on dung beetles, which are adversely affected by both grazing intensification and abandonment of extensive grazing. On one hand, grazing intensification has being reported to reduce diversity and affect assemblage structure through a decline in larger dung beetle species (Jankielsohn et al., 2001; Negro et al., 2011a; Numa et al., 2012). Trampling by livestock and changes in vegetation structure are important factors in these changes, although the use of veterinary medical products (especially antiparasitic drugs) and the increasing use of heavy machinery and ploughing (affecting beetle nests) may also be significant.

On the other hand, the abandonment of extensive grazing also has detrimental effects on dung beetles due not only to the decrease in resource availability but also to changes in habitat heterogeneity. A reduction in grazing intensity from moderate (1.5 livestock units/ha) to low (0.5–0.7 livestock units/ha) can adversely affect dung beetle diversity and assemblage structure, favouring more opportunistic species and eliminating large species (Tonelli et al., 2017, 2018). Lack of grazing by domestic livestock also increases reforestation, thereby reducing landscape heterogeneity, with detrimental effects on dung beetle diversity as most species are associated with open pastures (Barbero et al., 1999; Verdú et al., 2000; Macagno & Palestrini, 2009; Negro et al., 2011b; Tocco et al., 2013). Grazing by wild ungulates that occurs after livestock grazing has been abandoned has proved to be insufficient to preserve dung beetle diversity in Mediterranean areas, mainly because livestock have a greater impact in maintaining habitat heterogeneity and because the quality and quantity of the dung available changes (Barbero et al., 1999; Jay-Robert et al., 2008).

Furthermore, the replacement of mixed livestock farming systems (usually combining cattle, sheep and goats, but also pigs in dehesa systems in Spain) with holdings that specialise in a single species may also have negative impacts on dung beetle diversity and community structure due to the lack of different types of dung.

The effects of grazing by domestic livestock on dung beetle diversity fit the intermediate disturbance model: both grazing intensification and abandonment adversely affect dung beetle diversity (Negro et al., 2011b). Therefore, the preservation of dung beetle communities requires adequate levels of livestock grazing to maintain habitat heterogeneity and the availability of trophic resources.

Agriculture management constitutes one of the most important threats to threatened dung beetles: a case of agriculture intensification in a locality of *Jekelius punctatolineatus*, listed as Endangered. © J.R. Verdú

Scarabaeus sacer (Not Evaluated) and *Ateuchetus cicatricosus* (Near Threatened) run over on a road in Mamora, Morocco. @ R. Ugarte

BOX 6

IMPACT OF VETERINARY MEDICINAL PRODUCTS ON DUNG BEETLE DIVERSITY

The control of livestock parasites often requires the use of veterinary medical products that are mostly excreted in dung. Some of these products are hazardous to coprophagous invertebrates, in particular dung beetles, because they are highly resistant to degradation by abiotic and biotic factors and are also highly toxic. Their ability to accumulate in the environment and in living organisms is associated with the fact that they can move between food web compartments, which may lead to toxic effects after a longer period and on a larger spatial scale than in the case of products without these properties. Macrocyclic lactones (avermectins and milbemycins) have these effects, as do pyrethroids (mainly deltamethrin), which are faecally excreted and keep their insecticidal properties for several days or weeks after animal treatment, adversely affecting dung beetles and other insects that develop in dung (Lumaret et al., 1993; Floate et al., 2005; Adler et al., 2016; Nieman et al., 2018).

Even at low doses in droppings, many compounds used for the control of endo- and ectoparasites retain their insecticidal properties after intestinal transit, reducing the fertility of dung beetles and their ability to locate dung, increasing the development time of surviving offspring (the larval stages being more sensitive than adults) and threatening the ecosystem services they provide to pasture land. Recent studies demonstrate that low ivermectin concentrations in the dung can cause sub-lethal disorders in the sensory and locomotor systems of Mediterranean dung beetles (Verdú et al., 2015). These harmful effects have deleterious impacts on dung beetle communities, which in turn have serious consequences for the basic ecosystem functions that dung beetles provide in terms of dung burial and soil nitrification (Verdú et al., 2018; Tonelli et al., 2020), and also the reduction of greenhouse gas emissions from livestock faeces (Verdú et al., 2020). All these studies demonstrate that the role played by large-bodied roller dung beetles is especially important in Mediterranean ecosystems: these species are often those that contribute most to dung removal, but they are also the ones most affected by these chemical products due to their quick arrival at dung pats and their lower population growth rates.

We need to promote best practice in parasite management to prevent environmental pollution by these compounds.

Dung beetles dead after ingesting the droppings of horses treated with an anti-tick drug at Quénécan forest, in Brittany, France. © M. Le Billan.

In general, the longer the elimination time of compounds, the greater the environmental risk, not to mention the risk that parasites may develop resistance. Good parasite risk management consists in reconciling the economic and veterinary-health interests of livestock farmers and the ecological interests of the natural environment in a common approach, through the development of a sustainable and comprehensive policy for the management of parasitoses in ruminant livestock. It is not a matter of stopping the treatment of livestock but of adjusting it to limit or even suppress its non-target impact. The systematic and repeated use of the same substances by farmers leads to the development of parasite resistance, with the risk of prematurely limiting the therapeutic effectiveness of veterinary medical products, and the inevitable increase in doses that would be detrimental to dung beetles (Laing et al., 2017).

Antiparasitic treatments must be rationalised to increase efficiency and environmental sustainability by:

- Carefully choosing the most suitable drugs for the parasites and animal categories concerned, and avoiding the systematic, preventive and indistinct treatment of all the animals in a herd. The approach by category of animals grazing in the same place, or even by batch, is preferable.
- Targeting treatment specifically at the most vulnerable individuals. About 20% of animals are thought to host 80% of parasite populations, and not all individuals in the same batch have the same sensitivity to parasitism. Individual injections, which contain much less active substance than topical (pour-on) formulations, should be preferred. With endectocides, for example, the pour-on dosage for cattle is generally 2.5 times higher than by injection.
- Choosing a less harmful but therapeutically equivalent antiparasitic agent when periods of high livestock parasite risk coincide with the dung beetle breeding season (especially spring and autumn in the Mediterranean region).

Furthermore, organic farming of native breeds (which are better adapted to the local habitat and resources), properly integrated within the agro-silvo-pastoral system, should be promoted, alongside with holistic livestock management of livestock.

The inadequate use of veterinary medical products is the main long-term cause in the decline of dung beetle and therefore of the reduction in the rate of burial and disintegration of dung in agricultural ecosystems. ©J.R. Verdú

Due to the close association of some species with specific soil characteristics, quarrying and mining can be major threats by causing habitat loss, not only in the immediate area of exploitation but also as a consequence of the infrastructure required, such as roads.

Traditional extraction of cork through the use of draft animals in the Los Alcornocales Natural Park (southern Spain). The abandonment of this type of practice has led to a deterioration of Mediterranean ecosystems and a decrease in dung beetle populations. © J.R. Verdú

4. Recommendations for priority conservation measures

Despite their extraordinary biodiversity, heterogeneous landscapes of natural and agricultural habitats in the Mediterranean region are facing major losses of dung beetles due to human modification of natural ecosystems, pollution, residential and commercial development and farm management. Some protection measures are in place for either species or ecosystems, but they mainly aim to conserve the populations of a small number of species or to conserve certain natural areas in a variety of ways. The fact that many dung beetles are associated with natural open habitats and traditional agricultural landscapes with a moderate stocking density means that there are many areas where a rich diversity of dung beetles remains largely unprotected. Their protection status varies from one country to another, and there is an urgent need to implement conservation actions. The following section presents current conservation initiatives, as well as priority recommendations for the future conservation of Mediterranean dung beetle biodiversity.

International and regional instruments potentially relevant to the conservation and management of Mediterranean dung beetles

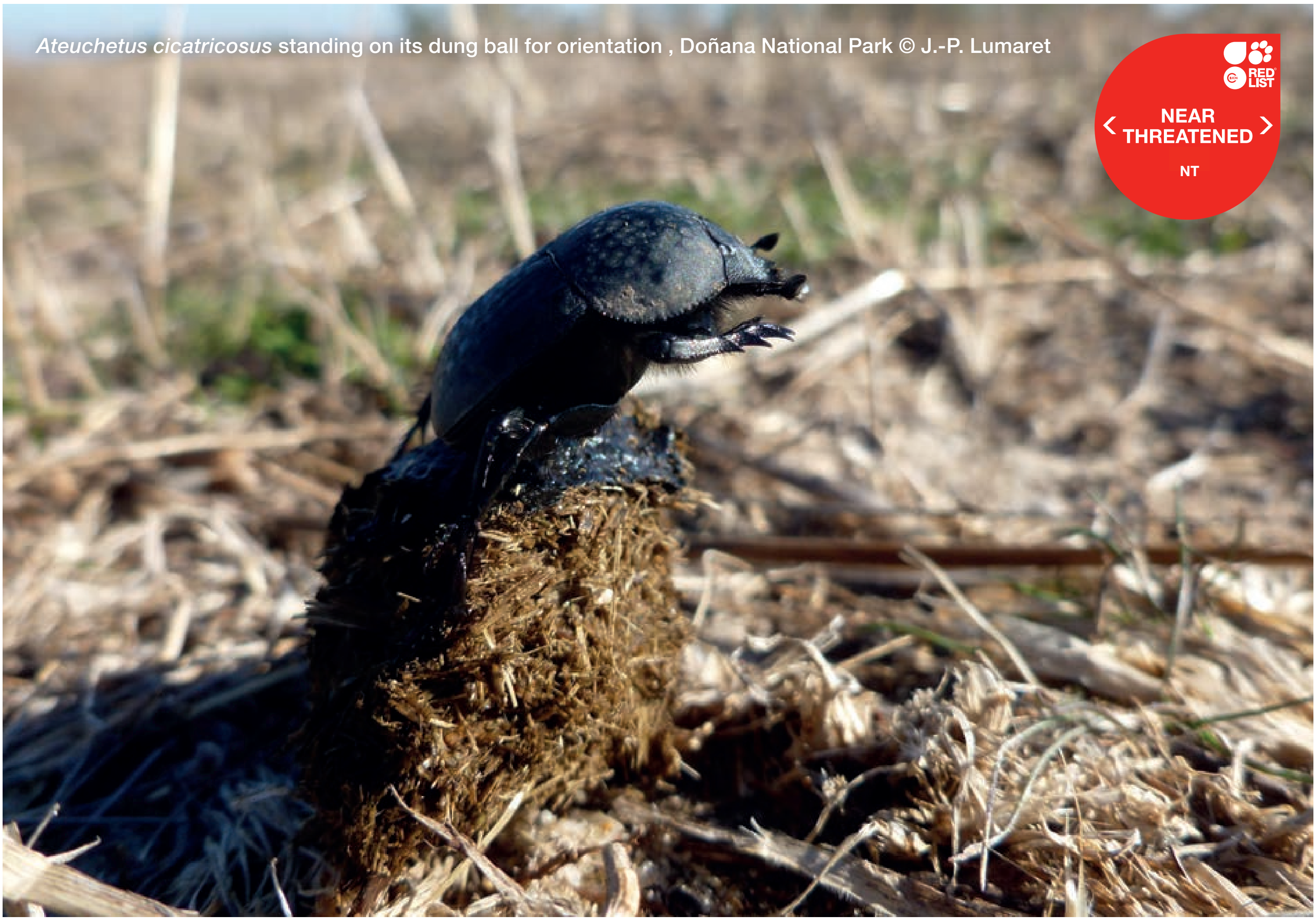
Mediterranean countries are signatories to a number of important treaties, conventions, agreements and regional instruments aimed at conserving biodiversity. The following are the most relevant to the conservation and management of the Mediterranean insect fauna. Currently, no dung beetle species are legally protected and listed in the appendices of regional or international conventions. More efforts are therefore needed to include protection for dung beetles under such instruments.

- ➜ **The Bern Convention on the Conservation of European Wildlife and Natural Habitats** – The Bern Convention is a binding international legal instrument that aims to conserve wild flora and fauna and their natural habitats, especially where the cooperation of several states is required. It covers all European countries and some African states. Fifty countries and the European Union have already signed up to the Convention and have committed to promoting national conservation policies, considering the impact of planning and development on the natural environment, enhancing education and information on conservation, and coordinating research (Council of Europe, 2016). Fifty-six insects are included in Appendix II for strictly protected animal species and two insect species are in Appendix III for protected fauna. Although 10 beetle species are included in Appendix II and one further species is in Appendix III, none of them are dung beetles.
- ➜ **Habitats Directive** – The Habitats Directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. Some 200 rare and characteristic habitat types are also targeted for conservation in their own right. The Habitats Directive is also known as *Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora*. It is a European Union Directive adopted in 1992 as an EU response to the Bern Convention. It is one of the EU's two directives related to wildlife and nature conservation, the other being the Birds Directive (http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm). Almost 1,000 species are included in Annex II for animal and plant species of community interest whose conservation requires the designation of special conservation areas. Ninety-nine of these species are insects, 36 of them beetles, but none is a dung beetle species.
- ➜ **CITES** – The Convention on International Trade in Endangered Species of Wild Fauna and Flora is implemented in the EU through a set of Regulations known as the EU Wildlife Trade Regulations. Currently these are *Council Regulation (EC) No 338/97 on the protection of species of wild fauna and flora*, which deals with the protection of wild plant and animal species by regulating trade therein. It lays down the provisions for import, export and re-export as well as internal EU trade in specimens of species listed in its four Annexes (http://ec.europa.eu/environment/cites/legislation_en.htm). Only two beetles are included in the CITES Annexes but neither of them is a dung beetle.

➜ **EU regulations on the use of antiparasitic drugs** – Release of veterinary medicinal products (VMPs) into the environment occurs directly via deposition of dung containing excreted VMP onto pastures or indirectly via application of VMP-contaminated manure on farmland. Council Directive 81/852/EEC (European Union, 1981; in force 1981–1991) required pharmaceutical companies submitting a new product for registration to provide information that would assist in the assessment of the risk that the compound might pose for the environment, including dung beetles. Risk is an estimate of the relationship between the level of exposure to a substance and the incidence and severity of an effect (van Leeuwen, 1995). Ecological or environmental risk assessments (ERAs) may find that species and processes could be exposed to these chemicals by a variety of routes (Koschorreck & Apel, 2006). A guidance document on how to perform an ERA was first prepared by the European Medicines Agency in 1997 (EMEA, 1997). Subsequently, the International Cooperation on Harmonisation of Technical Requirements for Registration of Veterinary Medicinal Products (VICH; www.vichsec.org/) established rules for performing ERAs on VMPs, and test methods for assessing the effects of veterinary pharmaceuticals on dung organisms were developed (OECD, 2010). Furthermore, the new Regulation (EU) 2019/6 on veterinary medicinal products states that, if appropriate, 'the Commission shall make a legislative proposal in order to introduce a simplified system for registering traditional herbal products used to treat animals' (Article 157). It requires manufacturers to carry out pharmacological, toxicological and residue and safety tests on all veterinary medical products (Annex II, requirement 6), and calls on the European Commision to take into account scientific recommendations of the European Medicines Agency to minimise the risk of cross-contamination, dissemination of these products in the environment and unintended administration to non-target animals (Recital 14).

➜ **Transhumance** – Transhumance is the seasonal movement of livestock from one grazing area to another along traditional drovers' roads (*tratturi* in Italian, *cañadas* in Spanish, *drailles* in French). This traditional form of pastoralism appeared several millennia ago in the Mediteranean region and strongly shaped the Mediterranean landscape. Transhumance, as an extensive form of pastoralism, provides several services including preservation of cultural landscape, protection of biodiversity, fire prevention, seed dispersal and the preservation of cultural diversity and traditions (Herzog et al., 2005; Oteros-Rozas et al., 2012). Its inscription in 2019 on the UNESCO Representative List of the Intangible Cultural Heritage of Humanity (https://ich.unesco.org/en/decisions/14.COM/10.B.2) attests to its importance. Some habitats and species involved in transhumance are listed in the EU Habitats Directive and can only be conserved by maintaining transhumance (Herzog et al., 2005). Despite its eco-cultural importance, transhumance is being abandoned throughout Europe (Bunce et al., 2004). Due to their link with livestock faeces for trophic and reproductive purposes, dung beetles are likely to suffer if transhumance disappears. Therefore, efforts should be made to maintain and support this practice for the sake of dung beetle conservation.

Organic livestock farming of indigenous breeds, integrated into the agro-sylvo-pastoral system, and managed under a holistic approach which includes controlled grazing and health care mainly based on natrual therapies, is one of the main alternatives for sustainable and biodiversity-friendly livestock farming. ©J.R. Verdú



Ateuchetus cicatricosus standing on its dung ball for orientation , Doñana National Park © J.-P. Lumaret

5. Conclusions and recommendations

This report presents the first regional IUCN Red List assessment of the endemic and near-endemic dung beetle fauna of the Mediterranean region. The distribution ranges of 634 taxa were examined, and 200 species that were found to be endemic or almost endemic to the region were assessed for their risk of extinction (Appendix 1). It is estimated that 20%[1] of the species in the region are threatened. Twenty-five of the 200 species evaluated are threatened: 1 (0.5%) Critically Endangered, 21 (10.5%) Endangered and 3 (1.5%) Vulnerable. They are concentrated in the coastal habitats of the southern and eastern Iberian Peninsula, in Sardinia, and along the Atlantic and Mediterranean coasts of North Africa from Morocco to Tunisia. Other important areas are located in the inland mountains of the south-eastern Iberian Peninsula. Thirty-seven per cent of the assessed species are listed as Data Deficient in the Mediterranean region. Northern Africa, Mediterranean Turkey and the Levant are the areas where most of these poorly known species occur. Despite the current lack of data, these taxa should be acknowledged as being potentially threatened and highlighted as priorities for additional research and funding. Although limited data availability is often cited as a problem, it should not be used to justify a lack of management.

[1] This percentage is the mid-point value, which represents the best estimate of extinction risk and is calculated as follows: [(CR+EN+VU) / (Assessed-DD)] (IUCN 2011).

Dung beetles provide a wide range of environmental benefits, from nutrient cycling, soil aeration and reduction of carbon dioxide and methane emissions from dung pats to parasite control and secondary seed dispersal. They are also important in food webs not only as decomposers but also as prey for birds, bats and other insectivorous animals. Moreover, dung beetles support a range of other predators and parasites and coexist with a huge set of bacteria to extract nutrients from dung, many of them specific to individual species or groups of species (Shukla et al., 2016). However, details of dung beetles' ecological roles are still poorly understood and the current information gaps on their population status, trends and distribution reflect how little we still know about them (Schwab et al., 2016).

Changes in farming practices (intensification, overgrazing and grazing abandonment) and urban and infrastructure development are considered to be the biggest threats to dung beetles in the Mediterranean region, potentially affecting in one way or another most or possibly almost all of the species occurring there.

Urgent conservation measures are needed to improve the conservation status of Mediterranean dung beetles. In particular:

- National and international legislation should be fully implemented and revised to include the threatened species identified in this assessment. Collecting for scientific purposes should be facilitated to ensure that future conservation measures are effective and based on reliable data.
- Policies are needed to highlight the importance of preserving or introducing farming practices and livestock grazing systems that ensure that healthy natural and agricultural habitats are distributed heterogeneously throughout the landscape.
- Fieldwork and data collection on Data Deficient species should be prioritised to determine whether they need conservation action.
- More investment is needed in taxonomic studies and existing data from museum collections should be made more widely available in order to improve knowledge of the taxonomic status and phylogenetic relationships of some problematic species.
- Species and habitat action plans should be drawn up for the most threatened species.
- Dung beetle monitoring programmes should be set up in many more parts of the Mediterranean to provide detailed data on population trends. Only regular counts can provide the data needed to track the population trends of dung beetles in the region.
- Strong regional cooperation between experts must continue and new cooperation initiatives should be set up involving experts from countries where information is scarce, so that this first assessment of the conservation status of native Mediterranean dung beetles can be updated as new information becomes available.
- Increased funding should be made available from mechanisms such as the EU LIFE programme for conservation projects targeting threatened dung beetle species included on the Mediterranean Red List.
- Regional collaboration should be strengthened between Mediterranean scientists, amateur entomologists and national and local entomological societies so that information gaps can be filled in the countries where more knowledge is required, in order to provide a more comprehensive picture of the status of these species at national, regional and global levels.
- Campaigns are needed to raise public awareness of the importance of dung beetles in the functioning of natural and agricultural landscapes in the Mediterranean, their role in preserving healthy, balanced ecosystems, and the services they provide.

The Doñana Biological Reserve in the Doñana National Park, an ivermectin-free reserve with a well-preserved dung beetle assemblage characterized by the presence of threatened species: *Jekelius hispanus* and *Chelotrupes momus*. © J.R. Verdú

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Silphotrupes escorialensis, This species inhabits in *Quercus pyrenaica* wet forests in the Sistema Central in Spain. Listed as Least Concern. © J.R. Verdú

Chelotrupes momus, an Endangered dung beetle species endemic to the south-western Iberian peninsula associated to rabbit and sheep droppings. © J.R. Verdú

Appendix 1

Summary of regional IUCN Red List status of all Mediterranean dung beetle species assessed

(Red List assessments available at https://www.iucnredlist.org/)

Family	Subfamily	Species	Author	RL status	RL criteria	Endemic
Geotrupidae	Geotrupinae	*Allotrypes mandibularis*	(Reitter, 1896)	DD		✔
Geotrupidae	Geotrupinae	*Baraudia geminata*	(Gené, 1839)	LC		✔
Geotrupidae	Geotrupinae	*Ceratophyus hoffmannseggi*	(Fairmaire, 1856)	NT		
Geotrupidae	Geotrupinae	*Ceratophyus maghrebinicus*	Hillert & Král, 2013	DD		✔
Geotrupidae	Geotrupinae	*Ceratophyus martinezi*	Lauffer, 1909	EN		
Geotrupidae	Geotrupinae	*Ceratophyus rossii*	Jekel, 1866	EN	B1ab(iii)+2ab(iii)	✔
Geotrupidae	Geotrupinae	*Ceratophyus schaffrathi*	Hillert & Král, 2013	DD		✔
Geotrupidae	Geotrupinae	*Chelotrupes hiostius*	(Gené, 1836)	EN	B2ab(iii)	✔
Geotrupidae	Geotrupinae	*Chelotrupes momus*	(Olivier, 1789)	EN	B2ab(iii)	✔
Geotrupidae	Geotrupinae	*Geotrupes douei*	Gory, 1841	LC		✔
Geotrupidae	Geotrupinae	*Geotrupes ibericus*	Baraud, 1958	LC		
Geotrupidae	Geotrupinae	*Jekelius albarracinus*	(Wagner, 1928)	NT		
Geotrupidae	Geotrupinae	*Jekelius balearicus*	(López-Colón, 1985)	EN	B1ab(ii,iii)+2ab(ii,iii)	✔
Geotrupidae	Geotrupinae	*Jekelius brullei*	(Jekel, 1865)	LC		
Geotrupidae	Geotrupinae	*Jekelius castillanus*	(López-Colón, 1985)	EN	B2ab(ii,iii)	
Geotrupidae	Geotrupinae	*Jekelius catalonicus*	(López-Colón, 1991)	EN	B1ab(iii)+2ab(iii)	✔
Geotrupidae	Geotrupinae	*Jekelius chersinus*	(Delabie, 1954)	EN		
Geotrupidae	Geotrupinae	*Jekelius hernandezi*	(López-Colón, 1988)	EN	B2ab(iii)	✔
Geotrupidae	Geotrupinae	*Jekelius hispanus*	(Reitter, 1892)	EN	B2ab(i,ii,iii)	✔
Geotrupidae	Geotrupinae	*Jekelius intermedius*	(Costa, 1839)	LC		✔
Geotrupidae	Geotrupinae	*Jekelius juengeri*	(Romero-Samper, 1995)	DD		✔
Geotrupidae	Geotrupinae	*Jekelius marginatus*	(Poiret, 1787)	NT		✔
Geotrupidae	Geotrupinae	*Jekelius nitidus*	(Jekel, 1866)	LC		✔
Geotrupidae	Geotrupinae	*Jekelius punctatolineatus*	(François, 1904)	EN	B2ab(ii,iii,iv,v)	✔
Geotrupidae	Geotrupinae	*Jekelius sardous*	(Erichson, 1847)	EN	B2ab(iii)	✔
Geotrupidae	Geotrupinae	*Renaudtrupes distinctus*	(Marseul, 1878)	EN	B2ab(ii,iii)	✔
Geotrupidae	Geotrupinae	*Silphotrupes escorialensis*	(Jekel, 1866)	LC		
Geotrupidae	Geotrupinae	*Silphotrupes punctatissimus*	(Chevrolat, 1840)	EN		
Geotrupidae	Geotrupinae	*Thorectes armifrons*	(Reitter, 1892)	LC		✔
Geotrupidae	Geotrupinae	*Thorectes asperifrons*	(Fairmaire, 1866)	DD		✔
Geotrupidae	Geotrupinae	*Thorectes baraudi*	López-Colón, 1981	EN	B2ab(ii,iii)	✔
Geotrupidae	Geotrupinae	*Thorectes coiffaiti*	Baraud, 1969	EN	B1ab(iii)+2ab(iii)	✔
Geotrupidae	Geotrupinae	*Thorectes coloni*	Ruiz, 1998	CR	B1ab(iii)	✔
Geotrupidae	Geotrupinae	*Thorectes demoflysi*	(Baraud, 1965)	DD		✔
Geotrupidae	Geotrupinae	*Thorectes laevigatus*	(Fabricius, 1798)	LC		✔
Geotrupidae	Geotrupinae	*Thorectes latus*	(Sturm, 1826)	DD		✔
Geotrupidae	Geotrupinae	*Thorectes lusitanicus*	(Jekel, 1866)	NT		✔
Geotrupidae	Geotrupinae	*Thorectes puncticollis*	Lucas, 1846	EN		

Family	Subfamily	Species	Author	RL status	RL criteria	Endemic
Geotrupidae	Geotrupinae	*Thorectes reflexus*	(Jekel, 1866)	DD		✔
Geotrupidae	Geotrupinae	*Thorectes rugatulus*	(Jekel, 1866)	LC		✔
Geotrupidae	Geotrupinae	*Thorectes trituberculatus*	(Reitter, 1892)	DD		✔
Geotrupidae	Geotrupinae	*Thorectes valencianus*	(Baraud, 1966)	VU	B1ab(ii,iii)+2ab(ii,iii)	✔
Geotrupidae	Geotrupinae	*Thorectes variolipennis*	Marseul, 1876	EN	B2ab(iii,iv)	✔
Geotrupidae	Geotrupinae	*Trypocopris amedei*	(Fairmaire, 1861)	DD		
Geotrupidae	Geotrupinae	*Typhaeus typhaeoides*	(Fairmaire, 1852)	LC		✔
Geotrupidae	Lethrinae	*Lethrus fallax*	Nikolajev, 1975	NT		
Geotrupidae	Lethrinae	*Lethrus macrognathus*	Fairmaire, 1866	DD		✔
Geotrupidae	Lethrinae	*Lethrus rotundicollis*	Fairmaire, 1866	DD		✔
Scarabaeidae	Aphodiinae	*Acrossus carpetanus*	(Graëlls, 1847)	LC		
Scarabaeidae	Aphodiinae	*Acrossus siculus*	(Harold, 1862)	LC		✔
Scarabaeidae	Aphodiinae	*Acrossus tingitanus*	(Reitter, 1892)	LC		✔
Scarabaeidae	Aphodiinae	*Aganocrossus vejdovskyi*	(Balthasar, 1945)	DD		✔
Scarabaeidae	Aphodiinae	*Agoliinus pittinoi*	(Carpaneto, 1986)	DD		✔
Scarabaeidae	Aphodiinae	*Agoliinus ragusae*	(Reitter, 1892)	LC		✔
Scarabaeidae	Aphodiinae	*Agrilinus ibericus*	(Harold, 1874)	LC		✔
Scarabaeidae	Aphodiinae	*Ahermodontus ambrosi*	(Pardo Alcaide, 1936)	EN	B2ab(iii)	✔
Scarabaeidae	Aphodiinae	*Ahermodontus bischoffi*	(Všetečka, 1939)	DD		✔
Scarabaeidae	Aphodiinae	*Ahermodontus marini*	Báguena, 1930	DD		✔
Scarabaeidae	Aphodiinae	*Alocoderus carinifrons*	(Reitter, 1892)	NT		✔
Scarabaeidae	Aphodiinae	*Alocoderus mineti*	(Clément, 1981)	DD		✔
Scarabaeidae	Aphodiinae	*Amidorus cribricollis*	(Lucas, 1846)	LC		✔
Scarabaeidae	Aphodiinae	*Amidorus moraguesi*	(Baraud, 1978)	LC		✔
Scarabaeidae	Aphodiinae	*Ammoecius amplicollis*	(Peyerimhoff, 1939)	DD		✔
Scarabaeidae	Aphodiinae	*Ammoecius dentatus*	(Schmidt, 1908)	LC		✔
Scarabaeidae	Aphodiinae	*Ammoecius dogueti*	(Baraud, 1980)	DD		✔
Scarabaeidae	Aphodiinae	*Ammoecius elevatus*	(Olivier, 1789)	LC		
Scarabaeidae	Aphodiinae	*Ammoecius felscheanus*	(Reitter, 1904)	DD		✔
Scarabaeidae	Aphodiinae	*Ammoecius franzi*	(Petrovitz, 1964)	LC		✔
Scarabaeidae	Aphodiinae	*Ammoecius frigidus*	(Brisout de Barneville, 1866)	LC		
Scarabaeidae	Aphodiinae	*Ammoecius lusitanicus*	(Erichson, 1848)	NT		
Scarabaeidae	Aphodiinae	*Ammoecius naviauxi*	(Baraud, 1971)	DD		✔
Scarabaeidae	Aphodiinae	*Ammoecius numidicus*	Mulsant, 1851	DD		✔
Scarabaeidae	Aphodiinae	*Ammoecius rugifrons*	(Aubé, 1850)	DD		✔
Scarabaeidae	Aphodiinae	*Ammoecius satanas*	(Carpaneto, 1976)	DD		✔
Scarabaeidae	Aphodiinae	*Anomius annamariae*	(Baraud, 1982)	LC		
Scarabaeidae	Aphodiinae	*Anomius antii*	(Gridelli, 1930)	DD		✔
Scarabaeidae	Aphodiinae	*Anomius baeticus*	(Mulsant & Rey, 1870)	LC		✔
Scarabaeidae	Aphodiinae	*Anomius castaneus*	(Illiger, 1803)	LC		
Scarabaeidae	Aphodiinae	*Anomius crovettii*	(G. Dellacasa, 1983)	NT		✔

Family	Subfamily	Species	Author	RL status	RL criteria	Endemic
Scarabaeidae	Aphodiinae	*Anomius hamricola*	(Clément, 1928)	DD		✔
Scarabaeidae	Aphodiinae	*Anomius neidae*	(Petrovitz, 1971)	DD		✔
Scarabaeidae	Aphodiinae	*Anomius peyerimhoffi*	(Théry, 1925)	NT		✔
Scarabaeidae	Aphodiinae	*Anomius segonzaci*	(Bedel, 1904)	LC		✔
Scarabaeidae	Aphodiinae	*Anomius theryi*	Clément, 1962	DD		✔
Scarabaeidae	Aphodiinae	*Biralus mahunkaorum*	(Ádám, 1983)	LC		
Scarabaeidae	Aphodiinae	*Bodiloides ictericus ghardimaouensis*	(Balthasar, 1929)	LC		
Scarabaeidae	Aphodiinae	*Bodilus barbarus*	(Fairmaire, 1860)	LC		✔
Scarabaeidae	Aphodiinae	*Bodilus beduinus*	(Reitter, 1892)	LC		✔
Scarabaeidae	Aphodiinae	*Bodilus longispina*	(Küster, 1854)	LC		✔
Scarabaeidae	Aphodiinae	*Bodilus marani*	(Balthasar, 1929)	DD		✔
Scarabaeidae	Aphodiinae	*Calamosternus algiricus*	(Mariani & Pittino, 1983)	LC		✔
Scarabaeidae	Aphodiinae	*Calamosternus hyxos*	(Petrovitz, 1962)	LC		
Scarabaeidae	Aphodiinae	*Calamosternus mayeri*	(Pilleri, 1953)	LC		✔
Scarabaeidae	Aphodiinae	*Chilothorax brancoi*	(Baraud, 1981)	DD		✔
Scarabaeidae	Aphodiinae	*Chilothorax exclamationis*	(Motschulsky, 1849)	LC		✔
Scarabaeidae	Aphodiinae	*Chilothorax hieroglyphicus*	(Klug, 1845)	LC		
Scarabaeidae	Aphodiinae	*Chilothorax hucklesbyi*	(Paulian, 1942)	DD		✔
Scarabaeidae	Aphodiinae	*Chilothorax lineolatus*	(Illiger, 1803)	LC		
Scarabaeidae	Aphodiinae	*Chilothorax naevuliger*	(Reitter, 1894)	LC		✔
Scarabaeidae	Aphodiinae	*Chittius anatolicus*	(Petrovitz, 1963)	LC		✔
Scarabaeidae	Aphodiinae	*Esymus alkani*	(Petrovitz, 1963)	DD		
Scarabaeidae	Aphodiinae	*Esymus helenaeliviae*	(Dellacasa & Pittino, 1985)	LC		✔
Scarabaeidae	Aphodiinae	*Esymus sesquivittatus*	(Fairmaire, 1883)	LC		✔
Scarabaeidae	Aphodiinae	*Esymus sicardi*	(Reitter, 1892)	DD		✔
Scarabaeidae	Aphodiinae	*Euheptaulacus atlantis*	(Peyerimhoff, 1925)	LC		✔
Scarabaeidae	Aphodiinae	*Euheptaulacus nemethi*	(Théry, 1925)	DD		✔
Scarabaeidae	Aphodiinae	*Euorodalus boiteli*	(Théry, 1918)	NT		✔
Scarabaeidae	Aphodiinae	*Euorodalus elephanthinus*	(Petrovitz, 1967)	DD		✔
Scarabaeidae	Aphodiinae	*Euorodalus longevittatus*	(Schmidt, 1916)	DD		✔
Scarabaeidae	Aphodiinae	*Euorodalus tersus*	(Erichson, 1848)	LC		✔
Scarabaeidae	Aphodiinae	*Grandinaphodius inferorum*	Ziani, 2002	DD		✔
Scarabaeidae	Aphodiinae	*Grandinaphodius smoliki*	(Käufel, 1914)	DD		✔
Scarabaeidae	Aphodiinae	*Heptaulacus algarbiensis*	(Branco & Baraud, 1984)	DD		✔
Scarabaeidae	Aphodiinae	*Heptaulacus brancoi*	Baraud, 1976	NT		
Scarabaeidae	Aphodiinae	*Heptaulacus gadetinus*	Baraud, 1973	EN	B1ab(iii)+2ab(iii)	✔
Scarabaeidae	Aphodiinae	*Heptaulacus pirazzolii*	(Fairmaire, 1881)	DD		✔
Scarabaeidae	Aphodiinae	*Heptaulacus rasettii*	Carpaneto, 1978	LC		✔
Scarabaeidae	Aphodiinae	*Heptaulacus syrticola*	(Fairmaire, 1882)	DD		✔

Family	Subfamily	Species	Author	RL status	RL criteria	Endemic
Scarabaeidae	Aphodiinae	*Iberoaphodius dellacasai*	(Ávila, 1986)	LC		✔
Scarabaeidae	Aphodiinae	*Limarus hirtipennis*	(Lucas, 1846)	DD		✔
Scarabaeidae	Aphodiinae	*Liothorax isikdagensis*	(Balthasar, 1953)	DD		
Scarabaeidae	Aphodiinae	*Mecynodes anemurensis*	(Petrovitz, 1968)	DD		✔
Scarabaeidae	Aphodiinae	*Mecynodes angulosus*	(Harold, 1869)	DD		
Scarabaeidae	Aphodiinae	*Mecynodes leucopterus*	(Klug, 1845)	LC		
Scarabaeidae	Aphodiinae	*Mecynodes striatulus*	(Waltl, 1835)	LC		
Scarabaeidae	Aphodiinae	*Mecynodes trochilus*	(Reitter, 1892)	DD		✔
Scarabaeidae	Aphodiinae	*Melinopterus abeillei*	(Sietti, 1903)	DD		✔
Scarabaeidae	Aphodiinae	*Melinopterus sertavulensis*	(Pittino, 1988)	DD		✔
Scarabaeidae	Aphodiinae	*Melinopterus stolzi*	(Reitter, 1906)	LC		
Scarabaeidae	Aphodiinae	*Melinopterus tingens*	(Reitter, 1892)	LC		
Scarabaeidae	Aphodiinae	*Melinopterus villarreali*	(Baraud, 1975)	LC		✔
Scarabaeidae	Aphodiinae	*Mendidaphodius paganettii*	(Petrovitz, 1963)	LC		✔
Scarabaeidae	Aphodiinae	*Mendidaphodius palaestinensis*	(Petrovitz, 1963)	DD		✔
Scarabaeidae	Aphodiinae	*Neagolius heydeni*	(Harold, 1871)	DD		
Scarabaeidae	Aphodiinae	*Nimbus anyerae*	(Ruiz, 1998)	EN	B1ab(i,ii,iii,iv)+2ab(i,ii,iii,iv)	✔
Scarabaeidae	Aphodiinae	*Nimbus franzinii*	(Pittino, 1978)	LC		✔
Scarabaeidae	Aphodiinae	*Nimbus harpagonis*	(Reitter, 1890)	DD		✔
Scarabaeidae	Aphodiinae	*Nimbus johnsoni*	(Baraud, 1976)	LC		
Scarabaeidae	Aphodiinae	*Nimbus libanonensis*	(Petrovitz, 1958)	DD		✔
Scarabaeidae	Aphodiinae	*Nimbus orbignyi*	(Clouët des Pesruches, 1896)	LC		✔
Scarabaeidae	Aphodiinae	*Nimbus richardi*	(Veiga, 1984)	LC		✔
Scarabaeidae	Aphodiinae	*Nobiellus bonnairei*	(Reitter, 1892)	DD		✔
Scarabaeidae	Aphodiinae	*Nobius rhodiensis*	(Baraud, 1976)	DD		✔
Scarabaeidae	Aphodiinae	*Osmanius dellacasai*	(Petrovitz, 1970)	DD		✔
Scarabaeidae	Aphodiinae	*Paracoptochirus kozanensis*	Pittino, 2001	DD		✔
Scarabaeidae	Aphodiinae	*Paracoptochirus petrovitzi*	Branco & Baraud, 1988	DD		✔
Scarabaeidae	Aphodiinae	*Paracoptochirus vignai*	Carpaneto & Piattella, 1990	DD		✔
Scarabaeidae	Aphodiinae	*Parammoecius amanicus*	(Stebnicka, 1978)	DD		✔
Scarabaeidae	Aphodiinae	*Phaeaphodius fusculus*[1]	(Reitter, 1892)	DD		✔
Scarabaeidae	Aphodiinae	*Phalacronothus ambulans*	(Petrovitz, 1971)	DD		
Scarabaeidae	Aphodiinae	*Phalacronothus putoni*	(Reitter, 1894)	LC		✔
Scarabaeidae	Aphodiinae	*Plagiogonus esimoides*	(Reitter, 1892)	LC		✔
Scarabaeidae	Aphodiinae	*Plagiogonus nanus*	(Fairmaire, 1860)	LC		
Scarabaeidae	Aphodiinae	*Pseudacrossus koshantschikovi*	(Jacobson, 1911)	DD		
Scarabaeidae	Aphodiinae	*Pseudacrossus sharpi*	(Harold, 1874)	DD		✔

[1] Currently considered a junior synomim of *Esymus pusillus*

Family	Subfamily	Species	Author	RL status	RL criteria	Endemic
Scarabaeidae	Aphodiinae	*Pseudacrossus suffertus*	(Schmidt, 1916)	LC		✔
Scarabaeidae	Aphodiinae	*Pseudacrossus wewalkai*	(Petrovitz, 1971)	DD		✔
Scarabaeidae	Aphodiinae	*Pseudacrossus zuercheri*	(Reitter, 1908)	DD		✔
Scarabaeidae	Aphodiinae	*Subrinus vitellinus*	(Klug, 1845)	LC		
Scarabaeidae	Scarabaeinae	*Ateuchetus cicatricosus*	(Lucas, 1846)	NT		✔
Scarabaeidae	Scarabaeinae	*Ateuchetus laticollis*	(Linnaeus, 1767)	LC		
Scarabaeidae	Scarabaeinae	*Ateuchetus puncticollis*	(Latreille, 1819)	LC		✔
Scarabaeidae	Scarabaeinae	*Ateuchetus semipunctatus*	(Fabricius, 1792)	VU	B2ab(ii,iii,iv,v)	✔
Scarabaeidae	Scarabaeinae	*Ateuchetus variolosus*	(Fabricius, 1787)	LC		✔
Scarabaeidae	Scarabaeinae	*Bubas bison*	(Linnaeus, 1767)	LC		✔
Scarabaeidae	Scarabaeinae	*Bubas bubaloides*	Janssens, 1938	LC		
Scarabaeidae	Scarabaeinae	*Bubas bubalus*	(Olivier, 1811)	LC		✔
Scarabaeidae	Scarabaeinae	*Cheironitis furcifer*	(Rossi, 1792)	LC		
Scarabaeidae	Scarabaeinae	*Copris pueli*	Mollandin de Boissy, 1905	LC		✔
Scarabaeidae	Scarabaeinae	*Copris umbilicatus*	Abeille de Perrin, 1901	LC		✔
Scarabaeidae	Scarabaeinae	*Euonthophagus crocatus*	(Mulsant & Godart, 1872)	LC		✔
Scarabaeidae	Scarabaeinae	*Euonthophagus tissoni*	(Reitter, 1906)	LC		
Scarabaeidae	Scarabaeinae	*Gymnopleurus sturmii*	(MacLeay, 1821)	NT		
Scarabaeidae	Scarabaeinae	*Mnematium ritchiei*	MacLeay, 1821	DD		
Scarabaeidae	Scarabaeinae	*Onitis belial*	Fabricius, 1798	LC		✔
Scarabaeidae	Scarabaeinae	*Onitis ezechias*	Reiche & Saulcy, 1856	DD		
Scarabaeidae	Scarabaeinae	*Onitis ion*	(Olivier, 1789)	LC		✔
Scarabaeidae	Scarabaeinae	*Onthophagus albarracinus*	Baraud, 1979	VU	D2	✔
Scarabaeidae	Scarabaeinae	*Onthophagus andalusicus*	Waltl, 1835	LC		✔
Scarabaeidae	Scarabaeinae	*Onthophagus atricapillus*	d'Orbigny, 1908	LC		✔
Scarabaeidae	Scarabaeinae	*Onthophagus bonsae*	Zunino, 1976	DD		✔
Scarabaeidae	Scarabaeinae	*Onthophagus bytinskii*	Balthasar, 1960	DD		✔
Scarabaeidae	Scarabaeinae	*Onthophagus circulator*[2]	Reitter, 1891	DD		
Scarabaeidae	Scarabaeinae	*Onthophagus dellacasai*	Pittino & Mariani, 1981	LC		
Scarabaeidae	Scarabaeinae	*Onthophagus emarginatus*	Mulsant, 1842	LC		
Scarabaeidae	Scarabaeinae	*Onthophagus falzonii*	Goidanich, 1926	LC		✔
Scarabaeidae	Scarabaeinae	*Onthophagus hermonensis*	Baraud, 1982	LC		✔
Scarabaeidae	Scarabaeinae	*Onthophagus hirtus*	(Illiger, 1803)	LC		✔
Scarabaeidae	Scarabaeinae	*Onthophagus latigena*	d'Orbigny, 1898	LC		✔
Scarabaeidae	Scarabaeinae	*Onthophagus maki*	(Illiger, 1803)	LC		
Scarabaeidae	Scarabaeinae	*Onthophagus massai*	Baraud, 1975	DD		✔
Scarabaeidae	Scarabaeinae	*Onthophagus melitaeus*	(Fabricius, 1798)	LC		✔
Scarabaeidae	Scarabaeinae	*Onthophagus merdarius*	Chevrolat, 1865	NT		✔

[2] Nomen inquirendum

Jekelius punctatolineatus, an Endangered dung beetle endemic to the south-eastern Iberian peninsula associated to rabbit, sheep and goat droppings. © J.R. Verdú

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