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Morimus funereus,
a comprehensive report

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Contents

1 Species description and distribution

1.1 Taxonomy

Table 1: Taxonomy

Kingdom	*Animalia*
Phylum	*Arthropoda*
Class	*Insecta*
Order	*Coleoptera*
Family	*Cerambycidae*
Subfamily	*Lamiinae*
Genus	*Morimus*
Species	*M. asper*

Morimus funereus, commonly known as the funeral longhorn beetle, is a species of beetle (ord. *Coleoptera*) belonging to the family *Cerambycidae* (more information on conservation status of the family in the chapter 3.6), subfamily Lamiinae. The species was first identified in 1863 by Mulsant in France (Mulsant, 1863).

Until the early 2000's, the European species of the genus *Morimus* were considered a group of five species: *M. asper*, Sulzer, 1776; *M. funereus*, Mulsant, 1863; *M. orientalis*, Reitter, 1894; *M. verecundus*, Faldermann, 1836; *M. ganglbaueri*, Reitter, 1894 (Hardersen et al., 2017a). This classification was based only on morphological characteristics (size and pattern of elytra). A more recent study, using Cytochrome c oxidase and Internal transcribed spacer (ITS2) gene sequences (Solano et al., 2013), proposes that the Euro-Anatolian *Morimus* population represents one single morphologically and genetically variable species: *M. asper*, named according to the rules of the International Code of Zoological Nomenclature (*http://www.iczn.org/iczn/index.jsp*).

Since *M. funereus* was included in the Annex II of Habitat Directive as a species, considering the actual classification of subspecies (i.e. *Morimus asper funereus*), some researchers propose that this protection should be extended to *M. asper* sensu lato.

Even taking into account every possible discussion on taxonomy previously presented, in this report the species will be named as a separated species: *M. funereus*. The main reason is linked to the very poor quality of conservation data and reports of this subspecies. It is commonly associated with *M. asper*, a more common and well studied species. Since one of the main aims of this report is to highlight the lack of studies related to *M. funereus* and propose some ideas to improve the knowledge in the sense of conservation, the separation of the species seems the best option.

1.2 Morphology: Adults, Juvenile Stages and Identification

M. funereus is a typical holometabolic insect species. The ivory coloured eggs (4.5 x 1.2-1.6 mm) are characterized by a relief with stellate structures over the surface of the chorion (Romero-Samper & Bahillo, 1993). Between the different instars is not notable any difference in shape, just a great variation in size (first to last stage: 5 - 60 mm). With a white fleshy body and a sclerified head and small antennae, the larvae do not present legs (Romero-Samper & Bahillo, 1993). The pupa can be described as exarate (i.e. with free appendages), and initially white, darkens over time (Pavan, 1948a, 1948b; Romero-Samper & Bahillo, 1993).

With a length which vary between 16 and 38 mm, the body of the adults (Fig. 1, above) is elongated and oval shaped. The colour is light-grey with four well visible black spots on the elytra, which are grainy and fused together since is flightless (Hardersen et al., 2017a). Antennae are very long, as common in the Cerambycidae family. The length can be used as a parameter to distinguish the sexes: in males are longer (up to 7.5 cm), over the body length (Fig. 1, below), while in females are shorter (Parisi & Busetto, 1992). According to a field study on *M. asper* and *M. funereus* (Rossi de Gasperis, Passacantilli, Redolfi DeZan, & Carpaneto, 2016), the length of antennae vary between populations, and seems to be positively correlated with the frequency of mating.

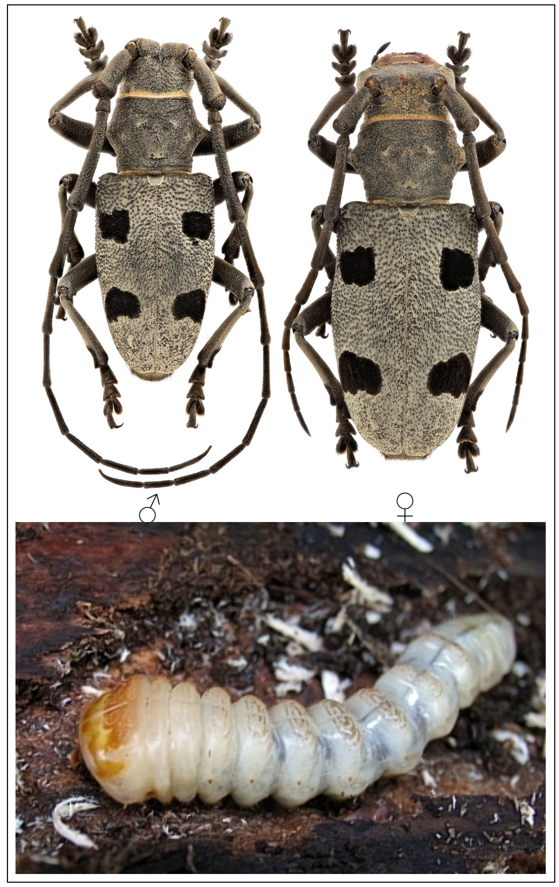


Figure 1: *M. funereus* sexual dimorphism (above) and *M. funereus* larvae (below) Photo by Lech Kruszelnicki and Slovenian National Museum of Natural History, respectively

This species (or subspecies, as previously discussed) is easily distinguishable from its congeneric *M. asper* by the background color of the body: the second one is darker (almost black) and the black spots are often invisible. Comparing to the other Italian longhorn beetle, the only similar species in shape and colour is *Herophila tristis* (Linneaus, 1767). This species is generally shorter (13 - 26 mm) and have thicker and shorter legs (Fig. 2). Another morphological distinction is the length of the first relatively to the third segment of antennae: in *M. funereus* the first is shorter, while in *H. tristis* is at least the same length or longer (Hardersen et al., 2017a).

Figure 2: Female individuals of *H. tristis* (left) and *M. funerus* (right)
Photo by Václav Hanzlík and U.Schmidt respectively

1.3 Identification

This longhorn beetle is not the most difficult to identify, in fact the light grey-blue colouration, with the four black spots, are easy to recognize over a tree bark. To the other side, *M. asper* is a bit more tricky to spot: since the entire exoskeleton is darker (mostly black), even if it's considered a quite big insect species, could be hard to find in the shadow of the canopy.

In order to help the citizens who join the LIFE MIPP (Sec. 6.2), the organizers produced different identification cards (Fig. 3), one each species. Every card published, included the *M. funereus* card, is published on the official LIFE project website and is correlated with a brief description of: taxonomy, morphology (dimorphism if present), life cycle, ecology and main threats for the species.

As a continuation of the LIFE MIPP, the project InNat (*https://www.innat.unimol.it*) born in 2017. On the website is available a smartphone application which could be used to collect and provide records of 30 selected species of insects protected by the Habitats Directive. On the website an identification card is provided for each species, with a good description of itself and of its taxonomic group (order level).

Figure 3: Photo from the LIFE MIPP's identification card of *M. funereus*. The card is for, as the website explain, *M. asper funereus*, in fact this picture present all the possible colouration of the insect species

For a more professional identification, and specific information are in need, a good field guide in French language is: *Guide des Coléoptères d'Europe* (Albouy V. and Richard D.; editor Delachaux et Niestle), which was translated in Italian too ("Guida ai Coleotteri d'Europa"; editor Ricca Editore).

1.4 Biology and Ecology

In this sub-section, the ecology and biology of *M. funereus* is explored. Since many authors consider it as a sub-species or a morphological variation of *M. asper*, the information in this chapter are a resume of different studies on this species. No difference between the sub-species were found, for this reason the description will still be referred to *M. funereus*.

M. funereus is considered as a primary saproxylic, which includes pioneer organisms that colonize the still intact wood of weakened or recently dead trees. These include beetle insects with strong jaws that enable them to dig tunnels through bark and into still hard wood. They are able to digest cellulose and specialize in using the cellular contents of the cambium and sapwood of the tree just below the bark, despite the presence of chemical defense elements of the tree still active (Campanaro et al., 2011).

This species is associated with forest environments, from the basal plane to the montane plane, up to about 1800 m of altitude, but is more common between 300 and 900 m (Hardersen et al., 2017a). With a preference for an abundant presence of large diameter dead wood (Campanaro et al., 2011), the species lives mainly in old-growth forests or well-structured woodlands, with a medium-high density of dead wood (Trizzino et al., 2013). This is a polyphagous species, the preferences include different deciduous and conifera genera (BENSE 1995): *Populus, Quercus, Fagus, Juglans, Tilia, Castanea* and the species *Abies alba* and *Pinus pinea* (Sama, 1988, 2002, for the presumed subspecies *Morimus asper asper*).

In Italy, phenology is related to altitude, but on the average adults can be found between May and September, with the period of greatest activity is generally around June (Campanaro et al., 2011). During the day is possible to spot some adults, but the peak of abundance is during dusk and the night (Hardersen et al., 2017b; Romero-Samper & Bahillo, 1993). By different authors (Polak & Maja, 2012; Stanić, Ivanović, Janković-Hladni, Nenadović, & Marović, 1985; Leonarduzzi, Zandigiacomo, & Maurizi, 2016) the peak of activity is considered dependent also on the temperature. Generally, under 17°C the activity of the individuals seems to drop. Around 12°C the species activity is practically null and adults, like during adverse weather conditions (i.e. rainy days), hide under bark cavities and soil holes (Polak & Maja, 2012).

Females oviposit in dead wood, with a great preference on standing dead and dying trees, but they do not reject freshly cut log piles, if the bark is still present (Campanaro et al., 2011). It is possible to find individuals also oviposing also over trunks and "young" stumps (Romero-Samper & Bahillo, 1993) but generally are considered as a meeting point for mating. Old stumps (i.e. trees cut more then one year before) and bark-less trees dead and dying trees are considered not attractive (Polak & Maja, 2012). The selection of the tree/stump is predominantly a male choice, which is followed by a "displaying posture" of the dominant male (Polak & Maja, 2012). The males which can't conquer an attractive dead-wood site wander around (Polak & Maja, 2012). In contrary, females seem to not have preferences on wood selection, but are more commonly sighted wandering away from trees, mating multiple times with different males (Polak & Maja, 2012).

Figure 4: *Morimus asper* shallow laying pits. Red arrows show a female of *M. asper* laying inside the shallow pit she had just dug, patrolled by the male (left picture), and shallow laying pits located on a fallen beech tree (right picture). Pictures took by S. Rossi de Gasperis (Rossi de Gasperis et al., 2016)

After mating, females create a little pit into tree barks in order to oviposit in them (which start around 16 days after emergences), while males show a mating-guarding behaviour (Polak & Maja, 2012). Wood selection for oviposing is made by the females, and can be different from the mating stump: large dead trunks with bark over it, fallen or standing trunks seems to not affect the selection. Trunks with a diameter less than 13 cm are not considered (Hardersen et al., 2017b). In one season then number of eggs a female can produce is more then one hundred (Stanić et al., 1985). After 9-12 days, larvae hatch from eggs and starting creating subcortical galleries, feeding of the wood (Romero-Samper & Bahillo, 1993). The last larval stage will create a long pupal cell (up to 8 cm) where the pupa mature for 18-23 days (Romero-Samper & Bahillo, 1993; Dojnov et al., 2012). When the adult form is complete, it requires 14-20 days before emergence, during which create an exit gallery on 8-12 mm diameter (Romero-Samper & Bahillo, 1993; Dojnov et al., 2012). The complete egg-adult cycle can last 3-4 years in total (Stanić et al., 1985), which considering the ability of overwintering of adults, and that can live more the one year (Stanić et al., 1985; Romero-Samper & Bahillo, 1993; Dojnov et al., 2012; Polak & Maja, 2012; Rossi de Gasperis et al., 2016), the total life span of *M. funereus* is considered very long.

1.5 Distribution

At the world scale level, *M. funereus* is present in central-south and east Europe. In particular, data distribution data assess its presence in 13 countries: Albania, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Greek mainland, Hungary, Italian mainland, Republic of Macedonia, Republic of Moldova, Romania, Slovakia (http://www.fauna-eu.org). It is necessary to underline the unreliability of the data, since some authors survey the species as a subspecies of *M. asper*, merging the data of the two taxonomic entity (authors note).

Even if the precise geographical distribution is not clear, the Italian distribution differ between the two subsp. *asper and funereus* quite clearly: the first is well distributed in country, were it inhabit every region of the peninsula, Sardinia and Sicily included; the second one occurs very scattered only in the north-west region of Friuli-Venezia-Giulia (Trieste and southern Gorizia provinces) (Hardersen et al., 2017b). The following map (Fig. 5 was build using data from CKmap and iNaturalist database.

The "Checklist e distribuzione della fauna italiana" (CKmap) is a database of the Italian fauna and GIS (Geographic Information Systems) data, available since 1995 (Minelli, Ruffo, & La Posta, 1993-1995). This tool is very useful to obtain data of distribution of Italian animal species, and in the first publication, it cover almost 85% of terrestrial and freshwater species (RUFFO & Stoch, 2003). Along the last 25 years, different update (on single or small groups of taxa) were made, but only in 2020 a real great and more complete update start, with LifeWatch Italy (Bologna et al., 2022). Due to the poor and specific updates, CKmap is a great data tool, but it cannot be very reliable until the final update will be published.

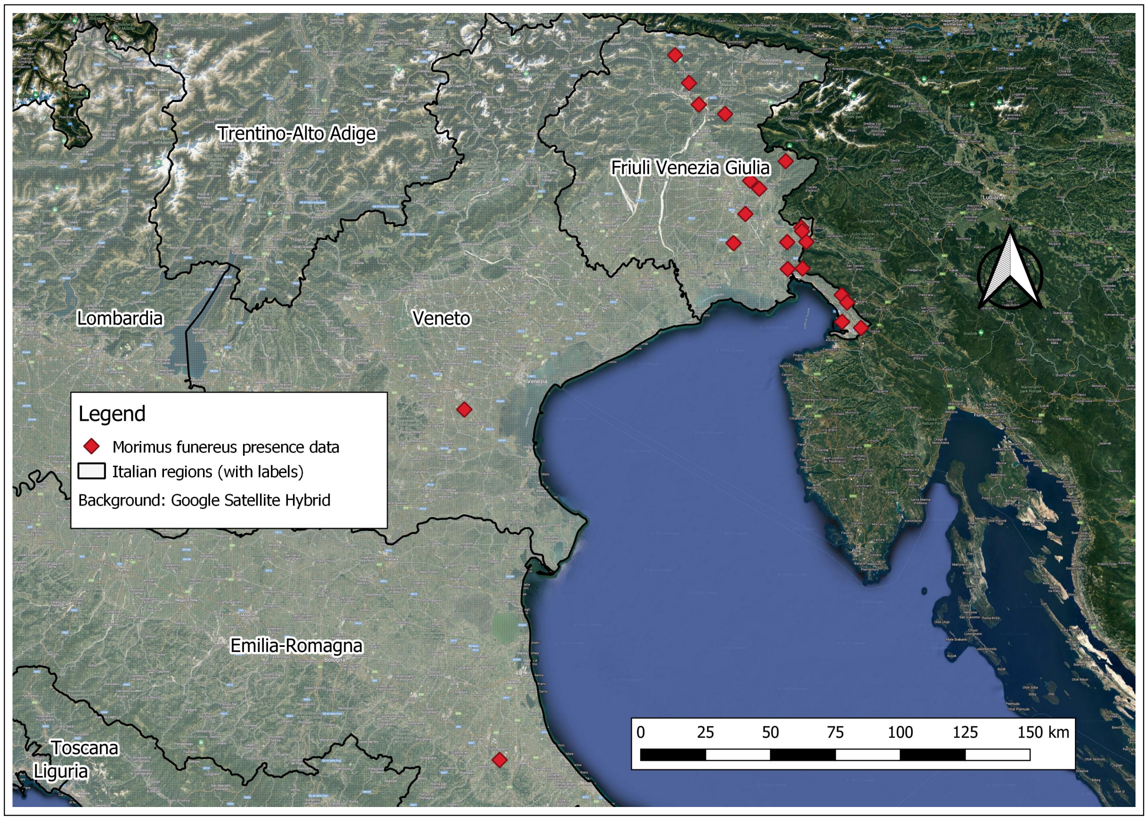


Figure 5: *M. funereus* Italian distribution map. Data from CKmap and iNaturalist's database. In the section 3.2.2, the map 12 shows clearly the origin of the data.

The iNaturalist project (https://www.inaturalist.org), is a social network based on mapping and data-sharing, with a world-wide community. Designed the first time as a Master's degree final project in 2008 (by Ken-ichi Ueda, Nate Agrin, and Jessica Kline - Berkeley's School of Information), nowadays is powerful tool available to any owner of a smartphone. The main aim is to obtain and share information (identification included) on every living being (bacteria excluded), at any expertise level: anyone can collaborate to the main project and to other specific, national and international. After the upload of a picture the identification, an integrated IA and other users, is made and the data is uploaded and available (with some restriction, see subsection 3.2, under "subpopulation" calculation). Due to it's citizen science nature, iNaturalist can lack of precise and scientific controls of the identification (which can be inaccurate or incomplete without an anatomical analysis) or the truthfulness and reliability of users data.

2 Threats and Legal status

At the present *M. funereus*, often named as *M. asper funereus* for the reasons explained in section 1, is considered threatened at different level. The species is included in the II annex of Habitat Directive, and it was assessed under the Article 17 as Unfavorable-Inadequate for most of the biogeographical regions (Tab. 2).

The *International Union for Conservation of Nature* (IUCN), since 1996, enlisted the species under the Vulnerable (VU) category at global scale (World Conservation Monitoring Centre, 1996). The same category was given at national scale, by the IUCN Red List of Italy (Audisio et al., 2014). Two years later (1998), the species was enlisted in the Bern Convention Annex I (Resolution n. 6).

	Conservation status (CS) of parameters						
Regions	Range	Population	Habitat	Future prospects	Current CS	Trend in CS	Previous CS (2012)
ALP	FV	FV	U1	XX	U1	+	FV
BLS	FV	FV	FV	FV	FV	=	FV
CON	FV	U1	U1	U1	U1	=	U1
MED	XX	U1	XX	U1	U1	x	U1
PAN	U1	U1	U1	U1	U1	=	FV
STE	FV	U1	U1	U1	U1	=	U1

Table 2: *Morimus funereus* EU biogeographical assessments. Data shown were selected from "Article 17 web tool", EU28 (period 2013-2018).

2.1 Main threats

Saproxylic beetles is one of the most threatened group of animal in Europe, since the main resource (i.e. dead wood) is decreasing in quantity and quality, due to the forest habitat reduction and not ecological-oriented management (Chiari et al., 2013). It is important to underline the scarcity of species-specific knowledge about this argument. Since the population data are hard to obtain (both adult and larval forms are not easily detectable), different threats are inferred or unknown (Tikkamäki & Komonen, 2011). Here the main threats of *M. funereus* are listed and briefly explained.

Taxonomy problem and conservation
Different authors (World Conservation Monitoring Centre, 1996; Carpaneto et al., 2015; Hardersen et al., 2017a), according to the new molecular proves, suggest that the protection status is referred only to subspecies, and it is necessary to extend the legislation to the entire species complex. In the last decade, this advice was followed by different authors in many reports, papers and projects (most of the research papers and LIFE projects cited

in this work use the nomenclature "M. asper funereus"). The problem linked to the classification can lead to confusion about older data, which are necessary for temporal changes studies. Moreover, in conservation studies, during the plan development, focusing on a species with different subspecies, could lead politicians and other stakeholders to focus on the major sub-group. Taking the example of *M. asper*, in a possible conservation program, do not consider the subspecies *M. a. funereus* could reduce the probability that a national program will work enough on its populations. This could be mitigated if it will be considered as a separated species.

Habitat loss and fragmentation

One of the main driver of population reduction is considered the habitat degradation and loss. In Europe continuous old forest, as at global scale, are critically reducing. Actually, the only areas with these characteristics could be found in Europe are at high latitudes, like Fennoscandia and North-West Russia (Jonsson, Svensson, Mikusiński, Manton, & Angelstam, 2019), but they are cold forest.

Many authors enlighten that the greater effects are not only to reduction of continuous forest area, but are directly related t the management. Old and dying trees removal, like branches and any dead wood sources has a direct impact on each stadium of life cycle of Cerambycidae species (Dojnov et al., 2012; Trizzino et al., 2013; Rossi de Gasperis et al., 2016). As cited by few studies different species (i.e. *M. asper, Rosalia alpina* and other xylophagous insects), even the construction and fuel wood stocks placed on the edge of the forest affect saproxylic beetles. An ecological trap effect of this structures was shown, and the problem is explained by their temporary nature: after some months (enough to be colonized by insects) the wood is removed and chipped (Hedin, Isacsson, Jonsell, & Komonen, 2008; Chiari et al., 2013).

It is important to remember the high impact of fragmentation of natural habitat too. Since the genus *Morimus* is flightless, and so considering the low dispersal ability, habitat fragmentation will negatively affect these insects (Thomas, 2000).

Thanks to its morphological and ecological characteristics, *M. funereus* its strictly adapted to the previously described habitat. It could be used so, as a biological indicator of the status of old, well structured forests.

3 IUCN Assessment

In order to produce the following extinction risk assessment on *Morimus funereus*, it was used the manual provided during the course and official IUCN guidelines, version 15.1 (July 2022). Based on the data in our possession, it was not possible to apply every criteria of the IUCN assessment. In order to complete this report, however, several factors that may influence extinction risk were evaluated, even if not supported by published data.

3.1 Criterion A: Past, present and future population reduction

Data on the size of the populations present in Italy of *M. funereus* cannot be found online. Given this lack of data, the trend of forest cover data in the Northern Italian Alps was obtained from literature (Bebi et al., 2017).

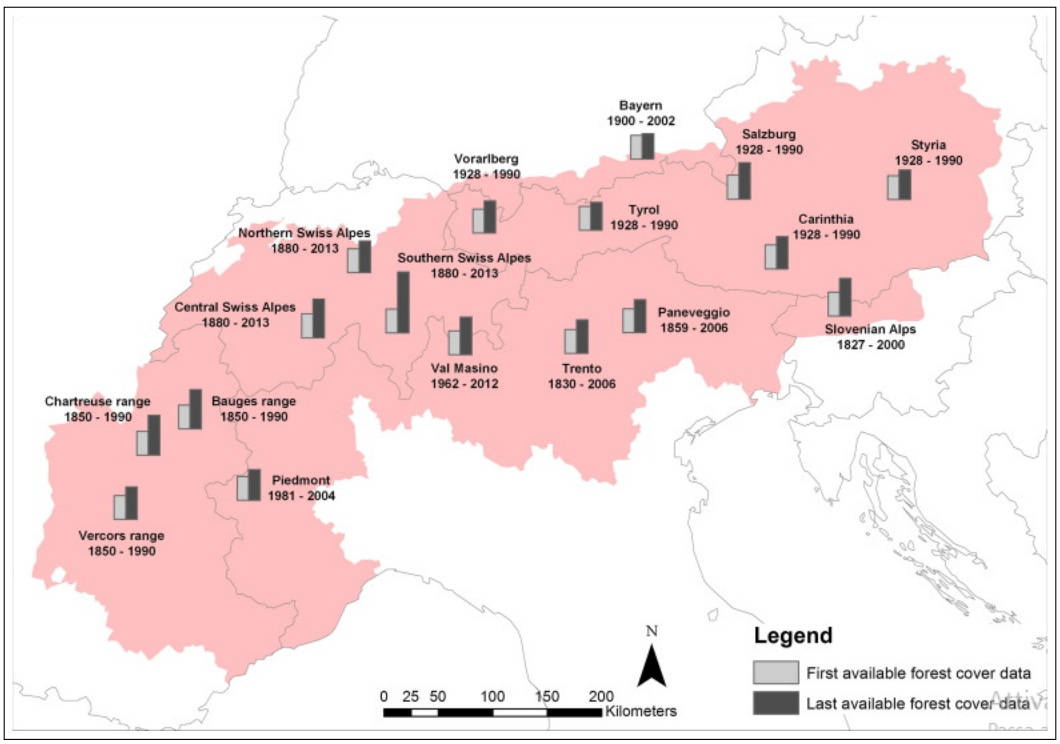


Figure 6: Forest cover changes in different Alpine regions compared to the first available data. The black bars represent the forest cover area during the last available survey; while the gray bars instead they represent the forest cover area related to the first available measurements (standardized to the same dimension of the bar for each region)

As can be seen from the figure above, the forest cover of the areas close to the Italian distribution of *M. funereus* has increased since the first measurements taken at the beginning of the 19th century. In the same study, authors focus on the increase of deadwood's volume at higher rates than those of the forest cover, on average between +39.3% and 105.8% per decade. Following these considerations we can deduce that the populations of *Morimus funereus* present in the area should remain stable, at least in relation to the habitat of the species, which the lost constitutes the greatest threat. Not assuming any decrease in populations in the last few years, we can therefore conclude that the species in question does not appear in any category of danger, therefore we propose its placement in the **NEAR THREATENED** (NT) category.

3.2 Criterion B: Restricted range and fragmentation, continuing decline or extreme fluctuations

The ***Extent of Occurrence*** (hereafter *EOO*), defined as the area contained within the shortest boundary (i.e. the minimum convex polygon, or MCP), which contains all the points of presence of the species is 14,405.543 km^2. The value is between 5,000 and 20,000 km^2 therefore the species belongs in the **VULNERABLE** (VU) category.

The ***Area of Occupancy*** (hereafter *AOO*), defined as the scaled metric that represents the suitable area currently occupied by the species, results in a total area of 756,453km^2 for which the species falls into the **VULNERABLE** (VU) category (*AOO* greater than 500 km^2 and less than 2000 km^2).

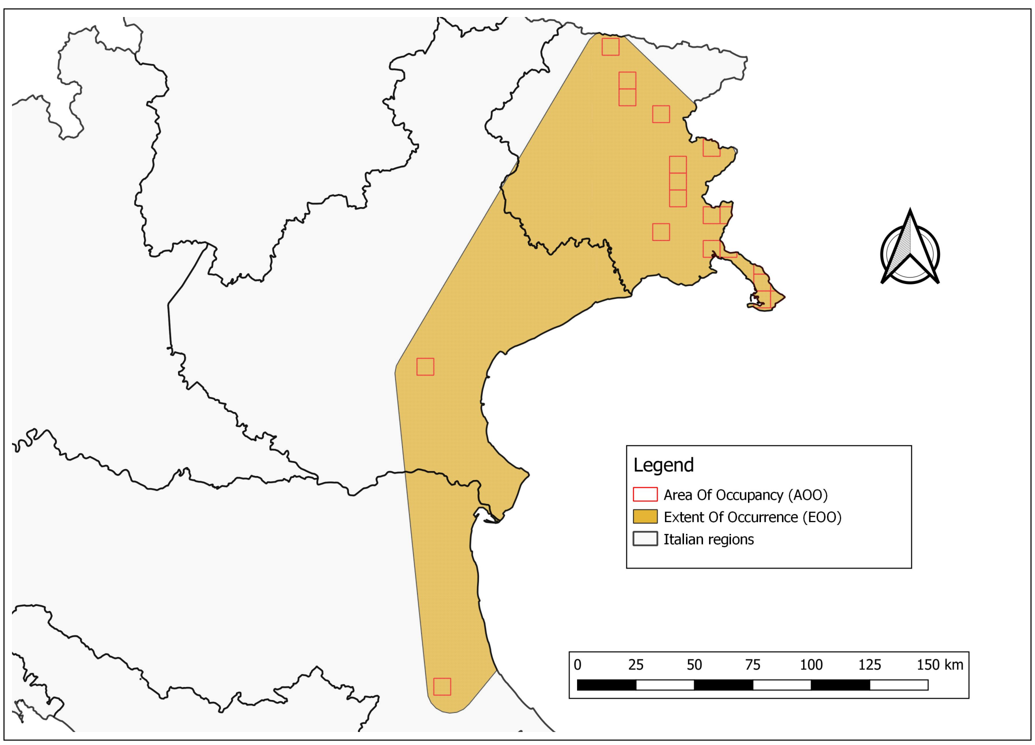


Figure 7: Extent of Occurrence and Area of Occupancy of Italian populations of *M. funereus*

The count of *locations*, the geographically and ecologically distinct areas in which a single threat can rapidly affect all individuals, is the second important point of analysis of this criterion. Regarding *M. funereus*, there is no data to suggest the presence of a specific threat to the species, the main threats identified for cerambycidae were then considered Europeans. Reference was made to the division of the *AOO* shown in the figure following.

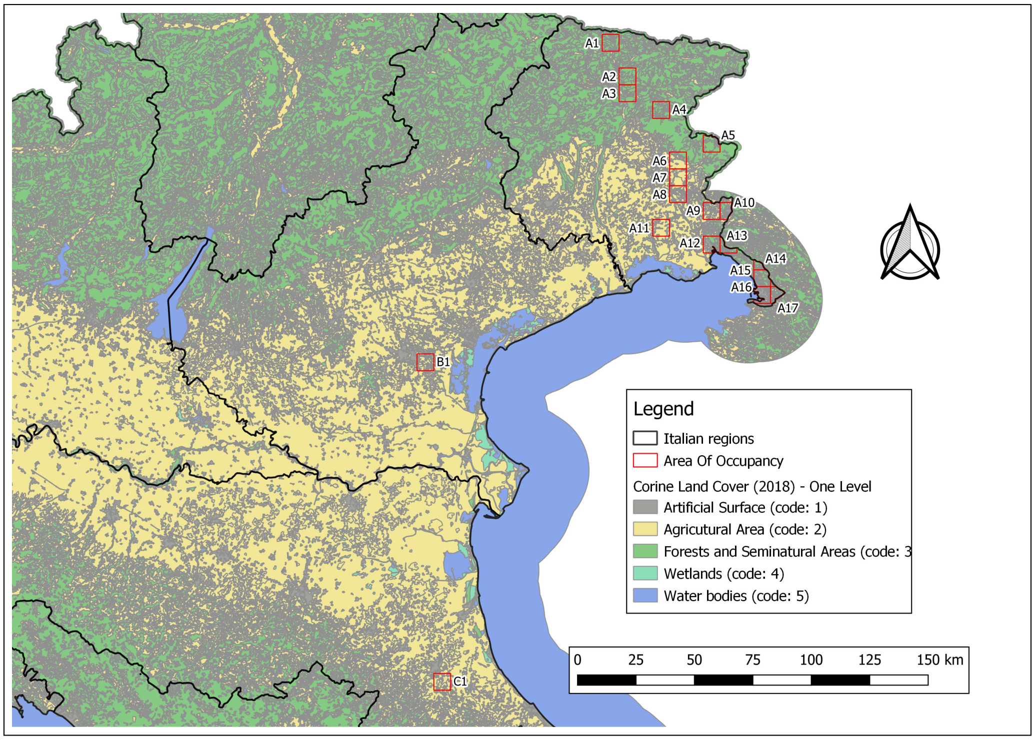


Figure 8: Numbered location from AOO analysis, over the Italian CLC map (2018)

The first and main threat taken into account is lost and fragmentation of habitat, due to the increase of urban and agricultural areas. The second edition of the WWF report "*Riutilizziamo l'italia*, 2014", reports that as of 2014, urbanization "*continues at a rate of 90 ha/day (about 10 m2/sec) of urban conversion, corresponding to almost 660,000 hectares in the next 20 years*". Assuming regular urbanization around the major urban centers of the region, we can assume that the areas *A3*, *A9*, *A10* and *A12-17* would be affected by this phenomenon. The total count of the locations is 11.

The second type of threat taken into account is fires. Only the map of the distribution of fires in Friuli Venezia Giulia was analyzed, since the two presence areas located in Emilia Romagna and Veneto are too isolated to constitute a single location.

As shown in this map, fires are always quite localized, especially in urban areas. We can therefore consider only areas *A2* and *A3* as an unified location, because they are adjacent to a wooded area. The other presence areas are considered as individual locations as they are located in an urban context, where fires remain very localized. Considering this type of threat, therefore, the total location count is 18. It is clear how the loss and fragmentation of

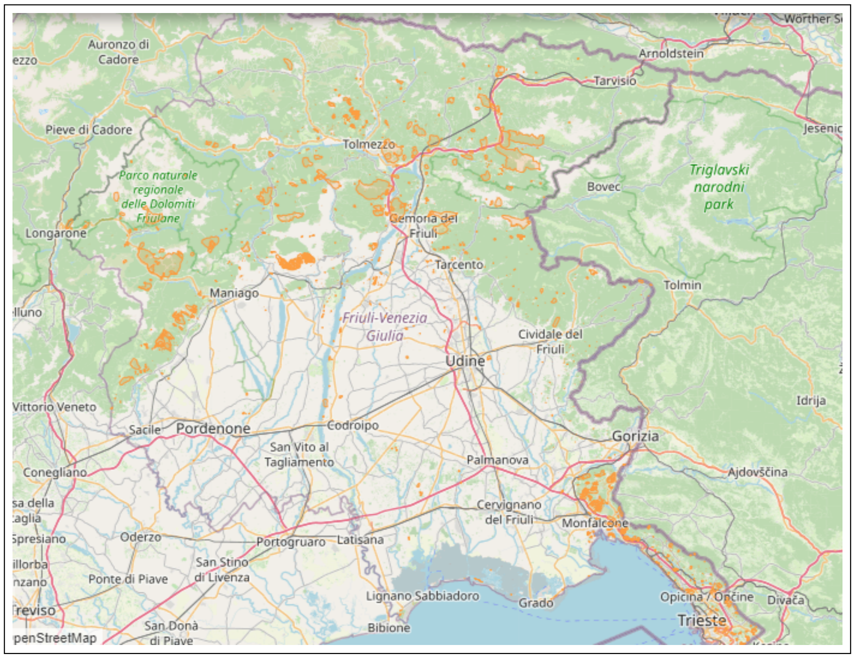


Figure 9: Fires distribution map of the Friuli Venezia Giulia region, 2018

habitat due to the increase of urban and agricultural spaces is the threat that weighs more heavily on the species, as evidenced by the great reduction in the number of locations compared to fires.

Subpopulations are defined as groups of the distinct individuals from the population, among which exist a little genetic or demographic exchange. Due to differences in the origin and quality of data, in this report the subpopulations are identified in two different ways. Both approaches are based on the dispersal ability of the species (i.e. 2 km) (Gabor, Vrezec, & Ratajc, 2018) and presence points obtained through *CKmap* and *iNaturalist*'s databases.

The social network iNaturalist collects data thanks to the users that publish georeferenced pictures of species of everything they encounter in nature. Due to its open-source nature, iNaturalist it could be dangerous for the threatened and rare species, revealing their position to anyone. To protect the most vulnerable taxa, the website hides the exact location, reducing the accuracy to 10 km.

The first approach is based on taking into account the uncertainty of iNaturalist data, including a 10km buffer to the dispersal ability of the species. As shown on the next map, this results in a 12 km buffer from the iNaturalist presence points and a 2km buffer from CKmap. The subpopulations that result with this method are 8.

The second approach removes the 10km uncertainty of iNaturalist. To every data is applied a 2km buffer, the dispersal ability, as shown in the following figure. Using this method the number of subpopulations increases to 19. Genetic and migration isolation increase due to

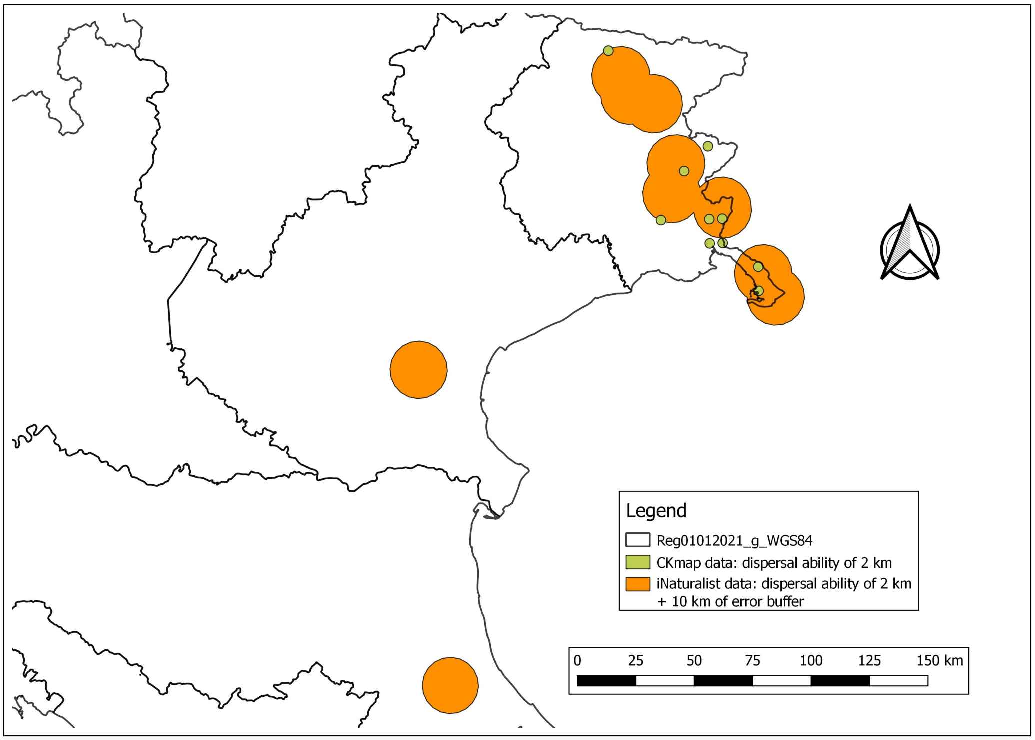


Figure 10: Italian subpopulations of *M. funereus*. Areas were obtained applying a 2 km buffer to each presence report. Due to the voluntary imprecision of iNaturalist's data (orange), it was added a 10 km buffer, reaching a total of 12 km diameter to every point. The data from CKmap show only the dispersal ability buffer

the low dispersal ability of the species (as it is wingless).

For greater accuracy, we recommend referring to this last analysis method as it is realistically unlikely that there is a connection between the subpopulations like the one shown in the first approach. Moreover, it was taken into account the maximum dispersal ability of was taken as a reference this species (2 km), when various works have average displacements in the space of 400/500 m.

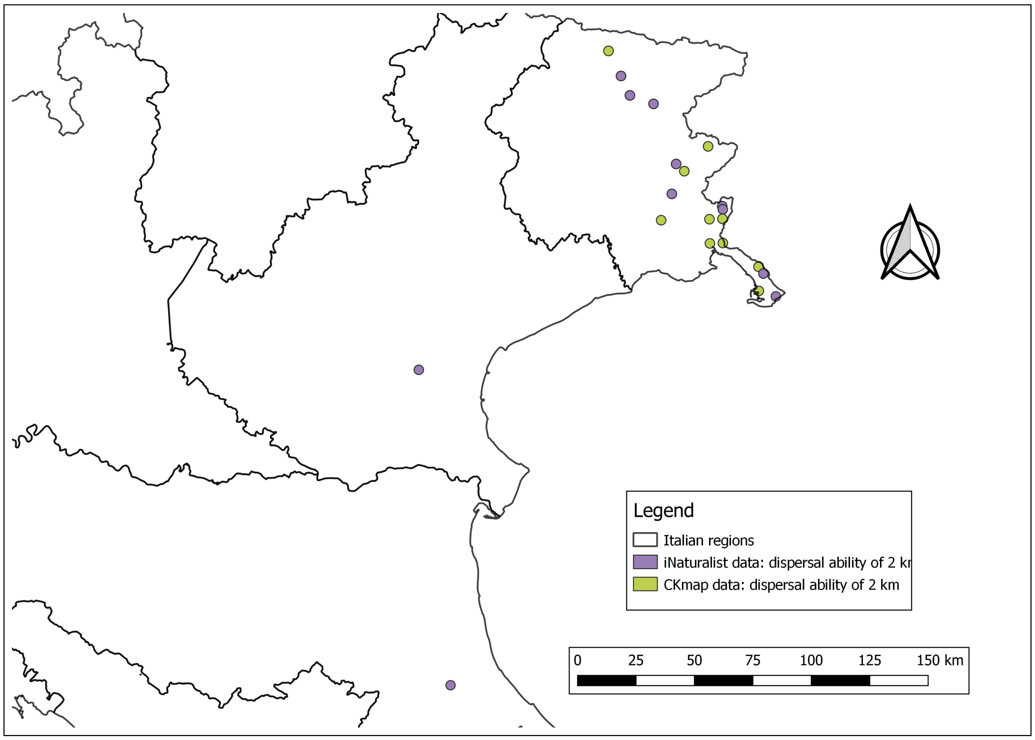


Figure 11: Italian subpopulations of *M. funereus*. Areas were obtained applying a 2 km buffer to each presence report. Data of different origins were divided by color, as legend shows.

3.2.1 Sub-criterion *a*

According to this view it is possible to indicate the range of the species as severely fragmented. There are very few subpopulations among which there may be a flow of individuals and/or genetic material for which the local extinction of one of them could not be compensated by another. For sub-criterion *a* therefore we classify the species as **VULNERABLE** (VU).

3.2.2 Sub-criterion *b* and *c*

Given the scarcity of data, it's not easy to give certain time indications regarding the reduction of *EOO*, *AOO*, habitat quality, in the number of locations or subpopulations, of mature individuals. However, the considerations made for criterion *A* on the increase in forest cover and deadwood biomass in the Alps was taken into account. Given this consideration, the populations and Italian range of *M. funereus* should remain at least stable for the foreseeable future. In support of this hypothesis was produced a map that compares the reports obtained from CKmap (in green) dating back to 2000, with those taken from iNaturalist (in purple) dating back to a time frame between 2012 and 2021. In the map 12 it is possible to notice a certain overlap of the observation sites and the number of observations between the two databases. According to the *Corine Land Cover* from 2018, some points of presence fall within urbanized areas or for agricultural use. Considering this it's likely that, within a few years, at least some of these populations will decline or become extinct since they are not located in a suitable area for the ecological needs of the species.

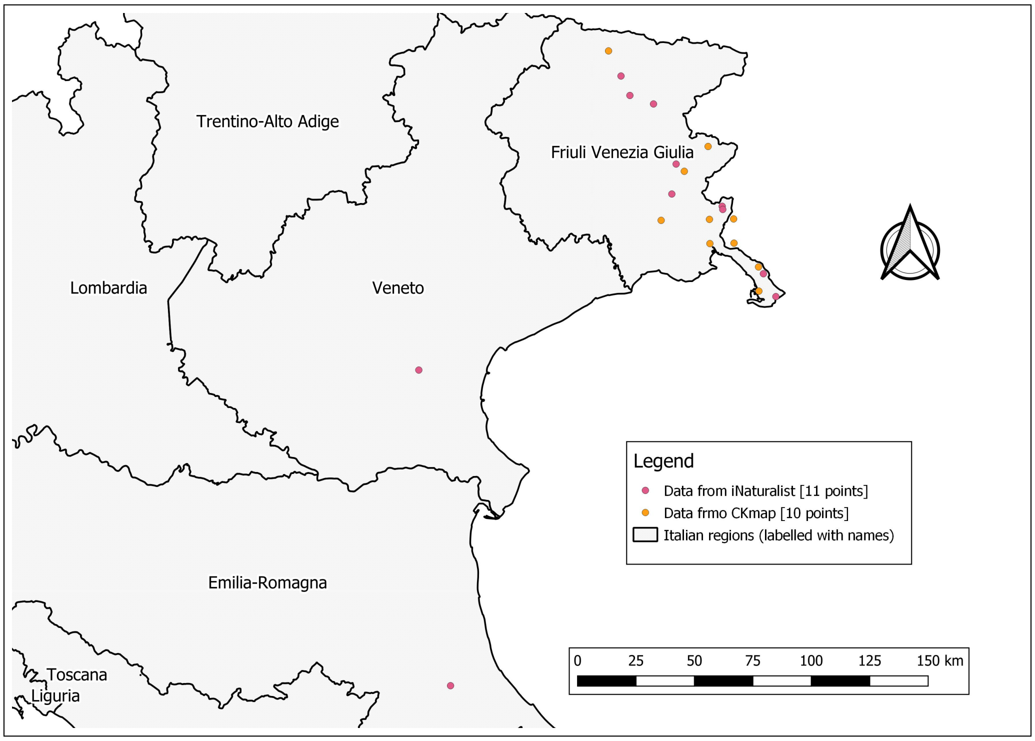


Figure 12: Points of presence divided by database: CKmap (yellow) and iNaturalist (red). For both of them a buffer (2 km) was added.

The limited data and inference made regarding the habitat of the species does not allow to draw completely reliable conclusions. Due to the assumed trend however, we propose as a classification, as regards the sub-criterion *b(i,ii,iii)* **NEAR THREATENED** (NT) while as regards sub-criterion *c* **DATA DEFICIENT** (DD)

3.3 Criterion C: Small population size and continuing decline

Due to the absence of data on mature/juvenile individuals in past and recent literature, it was estimated a number of mature individuals in each subpopulation.

In order to obtain a realistic value, this task was reached following the sampling session of Morimus asper (Rossi de Gasepris, 2016). Two sampling sessions of mature individuals of the species in 2013 and 2014, from April to July, the period of greatest activity for the adults of the species. The study was replicated in 3 areas of 40 ha each, contained in the

SCIs of "Mesophile Woods of Allumiere" (SCI IT 6030003), "Monte Fogliano and Monte Venere" (SCI IT 6010023) and “Monte Cimino (north side)” (SCI IT 6010022). A total of 458 individuals were marked in 2013 and 269 individuals in 2014. Considering the number of individuals marked each year and dividing it by the total study area (120 ha), we can hypothesize one average annual presence of 3.81 mature individuals per hectare in 2013 and 2.24 mature individuals per hectare in 2014. Since *M. asper* is much more widespread and common in Italy than *M. funereus*, it was chosen to use the value calculated for 2014.

Starting from the AOO map and attributing to each area a value of species occurrence probability, roughly estimated on the basis of the land use map, we'll have:

ID	**ha tot**	**Suitable%**	**Suitable ha**
A1	4729,769	60	2837,8614
A2	4751,196	70	3325,8372
A3	4761,928	70	3333,3496
A4	4772,674	60	2863,6044
A5	4270,294	80	3416,2352
A6	4804,989	40	1921,9956
A7	4815,787	30	1444,7361
A8	4826,597	30	1447,9791
A9	4786,815	30	1436,0445
A10	3056,343	30	916,9029
A11	4848,255	30	1454,4765
A12	4680,494	30	1404,1482
A13	2191,186	30	657,3558
A14	1381,812	30	414,5436
A15	4420,261	30	1326,0783
A16	4020,087	20	804,0174
A17	2529,279	30	758,7837
B1	4935,388	25	1233,847
C1	5145,407	30	1543,6221

Table 3: Estimated data on suitable area (ha) for *M. funereus*. The ID correspond to the codes in the AOO map (Fig.8)

Therefore, adding up the *AOO* values considered suitable for the species we obtain a total area of *32,541.42 ha*. Multiplying this value by the estimate of mature individuals per hectare per year, we are able to predict *72,893* adult individuals per year present in the sites we reviewed.

According to this estimate, *M. funereus* should be classified as NEAR THREATENED (NT), or even as LEAST CONCERN (LC) regarding the first part of the criterion C. However, is not possible to make predictions of continuous decline or highlight extreme fluctuations of population size. The final classification for criterion C is **DATA DEFICIENT** (DD).

For correctness, two sources of error should be highlighted. The estimate made cannot be accurate due to the fact that the habitats in which the sampling was performed differ from the areas in which the presence of *M.funereus* was evidenced, even if the plant species are appropriate to host both cerambycidae.

Another inaccuracy is that the study from which the population density was estimated was based on *Morimus asper* in the broadest sense (*M. funereus* and other subspecies) which is much more common in Italy than M. funereus, and therefore the density has certainly been overestimated.

3.4 Criterion D and E:Very small or restricted population and Quantitative

Following the estimation made in order to complete the previous criterion, the species is submitted under criterion D. Since the high number of mature individuals (12,482 total), *M. funereus* does not fall in any threatened categories. Based on this assumption, under this criterion, the species is evaluated as **LEAST CONCERN** (LC).

Unfortunately, the data available in literature does not permit to evaluate an extinction probability. The only information about the criterion *E* can be obtained from past Red List (World Conservation Monitoring Centre, 1996). From an more recent research (Solano et al., 2013), authors state the estimated population reduction (20%) over the last 10 years could be due to decline in quality and extent of habitat. These data are not sufficient to complete a correct evaluation required by the criterion *E*. Moreover, the statement from the last cited work is partially in contrast with the actual increase of the deadwood biomass in alpine region (*see criterion A*). In conclusion, the right classification under the criterion *E* is **DATA DEFICIENT** (DD).

3.5 Final Evaluation

The final evaluation of the conservation status of Morimus funereus within the Italian range is **VULNERABLE** (VU). According to the evaluation resulting from criterion *B1*, *B2* and sub-criteria *b* and *c*. Both criteria *B1* and *B2* attest that the species is classified as **VU** due to the limited extension of *EOO* and *AOO* respectively. The same results from the examination of sub-criterion *a*. For sub-criterion *b(i,ii,iii)* is instead **NT**, despite the scarcity of data available, the deductions made starting from the trend of the alpine forest cover, and short time frame in which our observations fall. The overall rating of Morimus funereus is then **VU B1,B2ab(i,ii,iii)**.

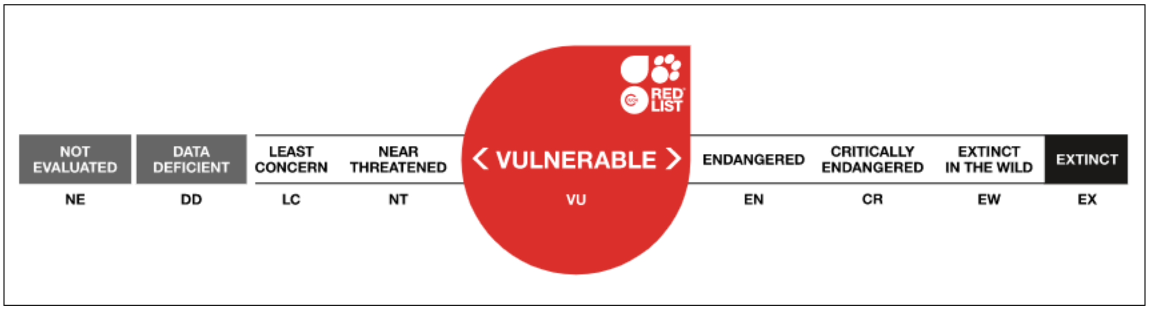
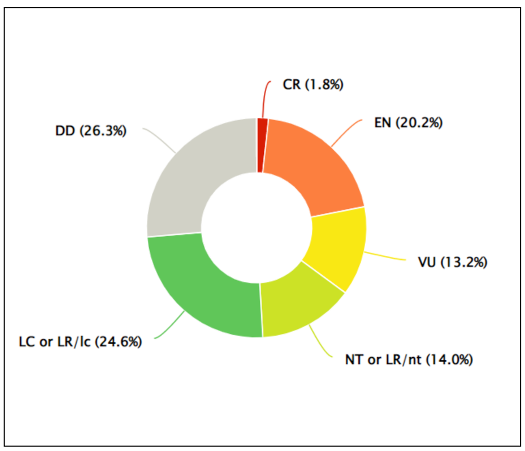


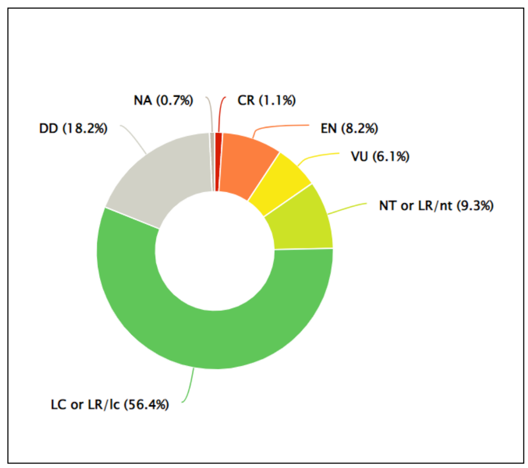
Figure 13: IUCN threats categories - Focus on the *M. funereus* category: Vulnerable (VU)

3.6 Actual IUCN assessment

Here are presented the data on the actual assessment status of the *Cerambycidae* family. The charts shown hereafter were produced by IUCN and available from the Red List website (*http://www.iucnredlist.com*).



(a)



(b)

Figure 14: Pie charts of the IUCN Red List of the family *Cerambycidae* (March 2023). Each colour correspond to a IUCN category. On the left (a) data from Global, on the right (b) data from European Assessment.

The total number of assessments are: 114 at global level, 280 at European level. Currently, both global and European assessments of the *Cerambycidae* family present a high number of species classified as Data Deficient (26.3% and 18.2% respectively). Notable is the number of species assessed as Least Concern (56.4%).

3.6.1 The species assessment

The IUCN assessment at the global level classifies the species as **VU A1c** (1996, IUCN). In this case, the complete absence of data regarding distribution, threats, and similar factors makes it difficult to make comparisons. However, since it is very old, it is possible to hypothesize that the use of criterion *A1c* is related to the loss of forest habitat that Europe has experienced in previous years. This is indeed the reason why this species was included in the Bern Convention in the same year. The range reported in this assessment includes Belgium, Czech Republic, Germany, Hungary, Moldova, Montenegro, Romania, Serbia, Slovakia, and Ukraine.
The presence of the species in Italy is not mentioned, probably due to the fact that it had not yet been recorded or due to the minor voice that Italian experts had in that forum.

At European level, it is not available any assessment, is in fact classified as **NOT EVALUATED** (NE).

The Italian red list of saproxylic beetles compiled in 2014 classifies the species as **VU B1ab(iii,iv)** (Audisio et al., 2014). There are notable similarities with the classification proposed in this case since the criteria used are almost the same. Unfortunately, due to the lack of specific data on *M. funereus* in the aforementioned red list, it is difficult to make comparisons. However, in the calculation of locations, the most important threat identified for the species corresponds to the major threat also highlighted in the red list in question.

4 Population Viability Analysis

In this chapter, the extinction probability and the Population Viability Analysis (PVA) of Morimus funereus is shown. Before presenting the results, a premise has to be made: since it is not a commonly studied species, in particular under quantitative aspects, most of the necessary values for the models were extrapolated from old research papers or estimated at the best of possibilities. Every population data hereafter will be correlated with the bibliographic source and the reason it was selected as the best for this type of analysis.

4.1 Site Selection and Population Data

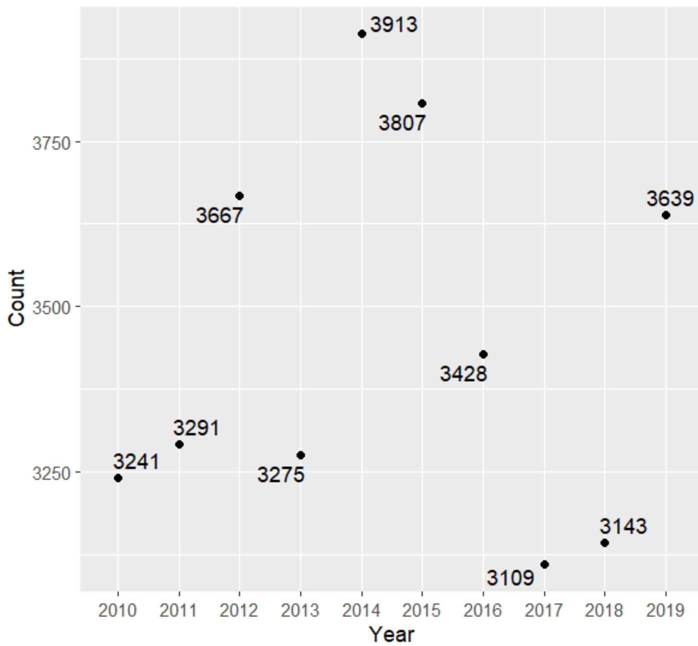
The area selected for the analysis aforementioned, we select the population in the areas named A2 and A3 of the previously calculated Area Of Occupancy. The area was chosen because it is formed mainly (70%) by forest habitat (Copernicus, 2018) and that could potentially host more individuals in a radius lower than the dispersal ability of the species, allowing a solid gene flow.

The fragile point in this chapter is related to the population size estimates, since there is no solid quantitative analysis on the species. In order to complete the analysis then, the data were obtained from a randomization with R language support (R Core Team, 2022). To avoid a general randomization, some limitations were added to the code. Starting from one population size value, estimated in a natural reserve in Lombardy region (Chiari et al., 2013), an upper and lower limit was applied to the stochastic generation of our population counts. The passages for this operation are the subsequent:

i. Authors estimated the population size from Mark Release Recapture data and different statistical models. In this report it is used the value from Royle Repeated Count (Royle & Nichols, 2003; Royle, 2004), since is one of the most accurate (Coefficient of Variation = 18%) and tends to underestimate the estimated value - which is considered better under a conservation biology view (Tikkamäki & Komonen, 2011).

ii. The population estimated from this research paper was 139 individuals (SE = 25) in 'Bosco Fontana' Natural Reserve (Site Nature 2000: IT20B0011; UTM WGS84 32T 636632 5006732, 25 m a.s.l.), an area of about 230 ha. This value was converted using the same individual/hectares ratio (), to obtain the basic value of 3396 individuals in the selected area (6 659.19 ha).

iii. The randomization was based on the '*runif*' function in R language (R Core Team, 2022). The parameters of minimum and maximum value were set based on the coefficient of variation of 18%. The year-count data and the plot are presented in the next figure.



	Year	Count
1	2010	3241
2	2011	3291
3	2012	3667
4	2013	3275
5	2014	3913
6	2015	3807
7	2016	3428
8	2017	3109
9	2018	3143
10	2019	3639

Figure 15: Scatter plot and table of the dataset used to perform the PVA

4.2 Carrying capacity of the analyzed area

The second necessary parameter for this analysis is the Carrying Capacity (K), the maximum number of individuals the natural area can support. For this value, the species density of 3.03 indiv./ha was obtained from the average density presented in another study (Rossi de Gasepris, 2016). Applying this value to the selected area, the carrying capacity that was used in this analysis is

$$K = 20177.35$$

4.3 Population Viability Analysis: Models

The threats hypothesized in the calculation of the minimum viable population are: forest management, urbanization, fires. These threats were chosen because, according to IUCN, the most impacting factors on Italian saproxylic are the loss of habitat and the loss of its quality (removal of dead wood) which are therefore well explained by urbanization and forest management. Fires, on the other hand, are the most destructive natural threat to the species. Events such as restocking and/or introductions have not been taken into consideration here as the actual number of populations present is not known.

To resume these threats and their estimated value of occurrence and the probability of survival of the population, the single value are presented in the table 4.

4.3.1 Density-Independent Model

The first future population analysis here presented, does not consider the population density. For this model, the finite growth rate λ is the only growth coefficient inserted, and it's standard deviation is included as value of environmental stochasticity. The above mentioned threats were not considered in this model.

$$mean\ \lambda = 1.018515 \qquad sd\ \lambda = 0.1139695$$

Starting from the simulated population data previously shown, the extinction probability in 100 years was calculated. With an initial population size of *3639* individuals, the model show a 0% probability of extinction.

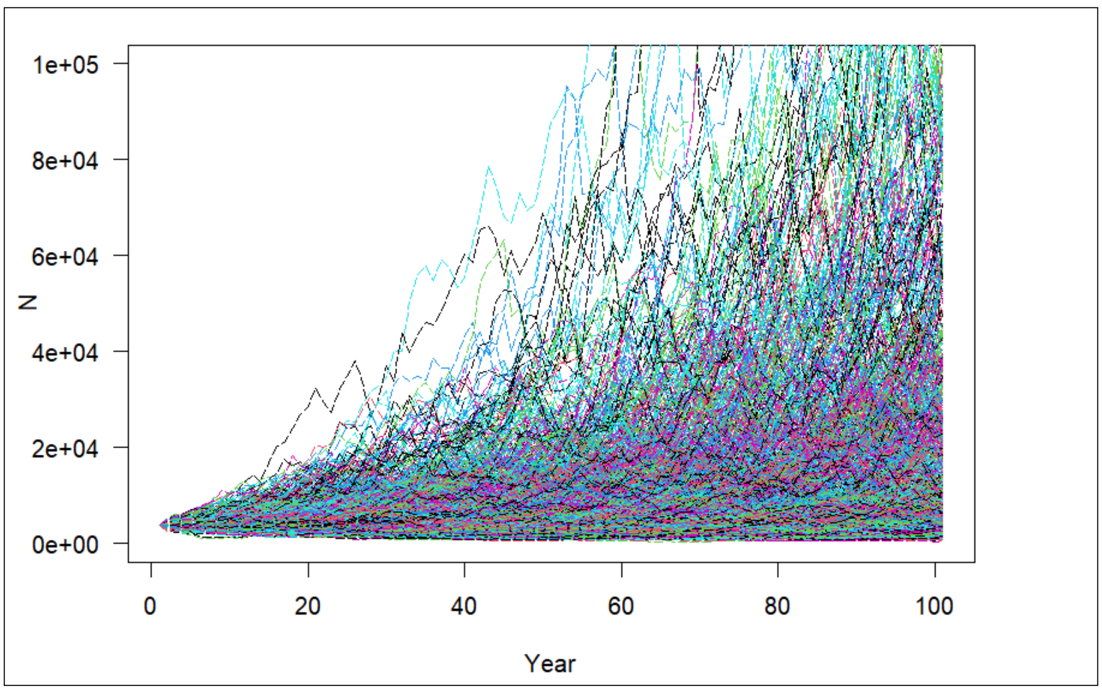


Figure 16: In this plot are show all the 1000 simulation produced by the density-independent model - each color represent one simulation

Even if from this model the population seems to be healthy and statistically able to survive along the next 100 years, clarifications have to be made:

i. Population size estimation is based on one, old data

ii. Carrying capacity and population size are estimated by the assumption that the different area were the species was surveyed, are ecologically similar and suitable in the same way

iii. Every data in this model come from old researchers who study *Morimus funereus* and *M. asper* together, without any distinction

4.3.2 Density-Dependent Model

The next model takes into account the density of the species. Since *M. funereus* is characterized by a discrete reproductive period, a discrete model is advisable. In particular, the Ricker model (Morris & Doak, 2002) is the one used for this analysis.

In this model, three different threats are take into account: Forest Management, urbanization, fires. These were chosen because, by the IUCN, the most important negative factors for Italian saproxylic are: loss of habitat and reduction of its quality (i.e. urbanization and dead-wood removal). Local wildfires instead, are the natural most destructive threat for this species. Immigration and emigration, like introductions were not added to the model, since it is not available the real number of individuals nor the metapopulation dynamics in the selected area. The next table shows the probability of occurrence of these events and the percentage of surviving population of the insect.

The population data are the same used in the precedent model, like the λ. As the first one, each model simulates (1000 times) the effects on the starting population for the next 100 years. Carrying capacity (K) and initial number of population (3639 individuals) are the same as the previous model.

As growth coefficient, for the density-dependent analysis, it was used the instant growth coefficient (r), specifically in the model formula the maximum coefficient of instant growth, calculated as follow:

$$\lambda_{max} = \lambda_{mean} + \lambda_{sd} \qquad\qquad r_{max} = \ln(\lambda_{max})$$

$$r_{max} = 0.1244139$$

Threats	Event's occurrence (%)	Probability of survival (%)
Forest Management	27	15
Urbanization	30	35
Fire	10	7

Table 4: Threats for *Morimus funereus*' population. Values of occurrence (%) and percentage of the survival individuals to the events.

The graph represents (from left to right, first to second row): PVA simulation of population trend, normal and log-scaled; extinction probability in 100 years (red line represents the extinction probability of 5%); final population abundance (green line represents the initial population).

In every model it is clear that none of the simulated populations survive to these threats (extinction risk over 5% in no more than 20 years). Interesting is the final abundance plot of the first graph: with this set of data, event occurrence and probability of survival, the final abundance of the population seems to be negative.

Forest Management

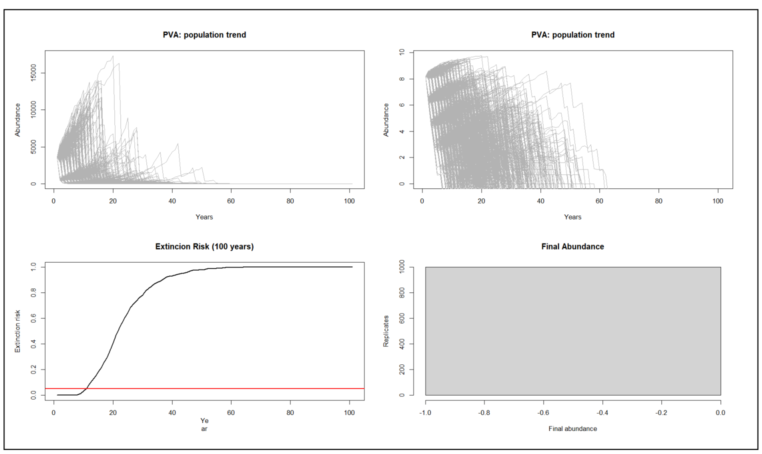


Figure 17: Density-Dependent model (Ricker model). This model is characterized by the add of forest management threat

Wildfires

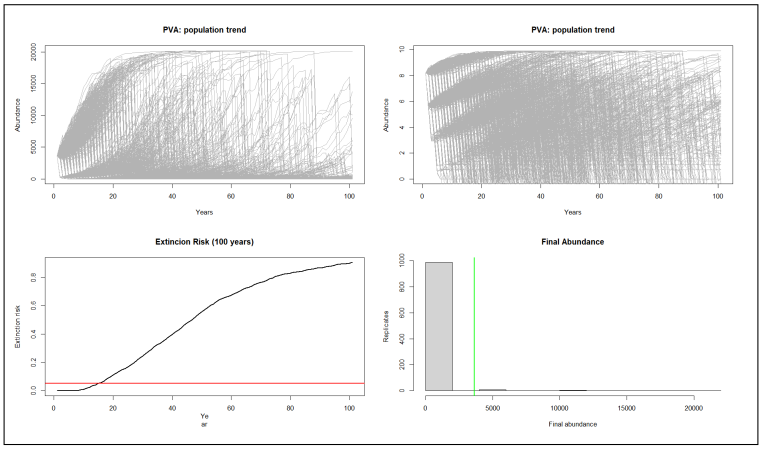


Figure 18: Density-Dependent model (Ricker model). This model is characterized by the add of wildfires threat

Urbanization

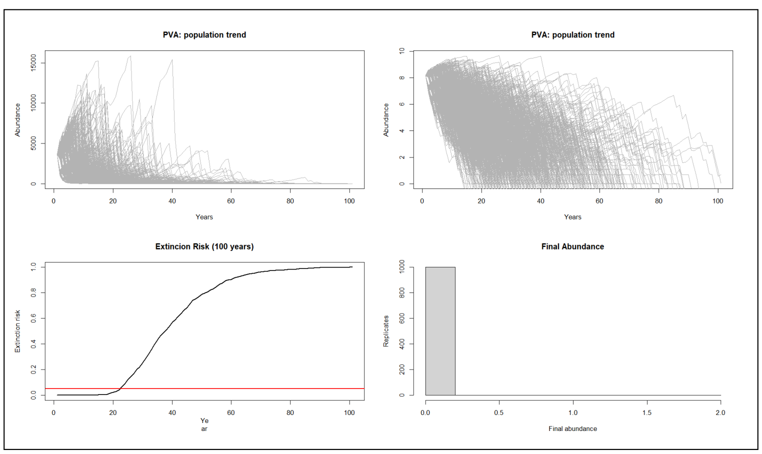


Figure 19: Density-Dependent model (Ricker model). This model is characterized by the add of urbanization threat

In order to study different trends, the same exact modelling were made a second time (Tab.5). The only difference with the previous one is related to the threats values: the occurrence probability was halved, the percentage of survival population was doubled. Hereafter the same-style plots are shown

Threats	**Event's occurrence (%)**	**Probability of survival (%)**
Forest Management	13	30
Urbanization	15	70
Fire	5	14

Table 5: Threats for *Morimus funereus*' population. Values of occurrence (%) and percentage of the survival individuals to the events.

Forest Management

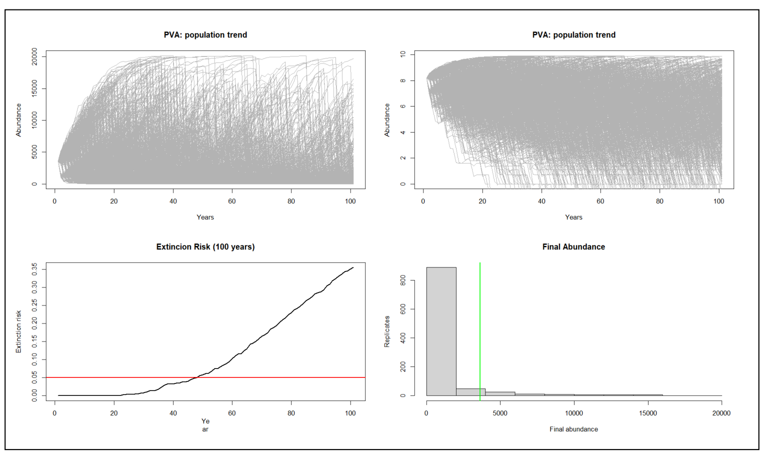


Figure 20: Density-Dependent model (Ricker model) - Second threat data. This model is characterized by the add of forest management threat

Wildfires

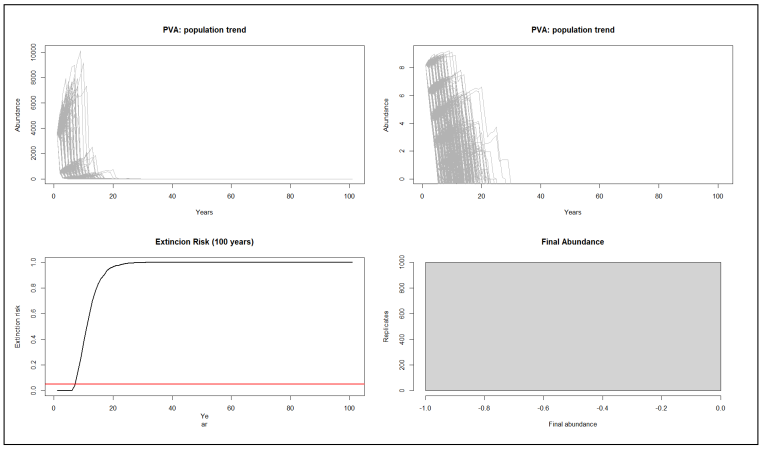


Figure 21: Density-Dependent model (Ricker model) - Second threat data. This model is characterized by the add of wildfires threat

Urbanization

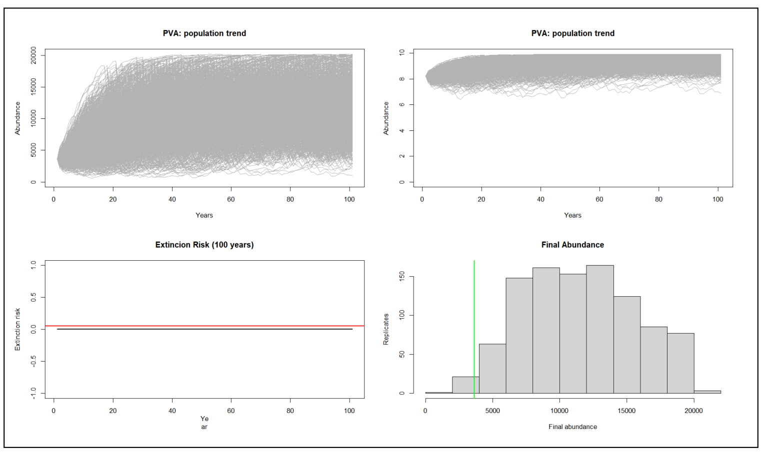


Figure 22: Density-Dependent model (Ricker model) - Second threat data. This model is characterized by the add of urbanization threat

Hypothetically, these new values can be considered as the results of an increase in conservation efforts. Since they are just estimated data, it is not possible to assess a realistic explanation to similar changes in values. Hereafter are presented some ideas about the causes of these improved values.

- Forest Management: establishment of not-managed areas, changes in forest management policies (e.g.. keeping a minimum quantity of deadwood or making freshly-cut log piles), where the species is already present and in adjacent suitable areas

- Wildfires: it is not possible to operate on the probability of wildfires, but with more environmentally-sensible policies some enhancement, a mitigation is achievable. With artificial firebreaks, the area of impact by wildfires is reduced. Moreover, the prohibition of controlling burning (e.g. for agricultural reasons) can drop the accidental fires probability.

- Urbanization: difficult to reduce or to limit very much, but it is possible to prevent a high impact on species during urban planning. Ecological corridors, buffer areas and correct communication (in order to enhance the citizens' awareness), can have a crucial role in this species conservation.

5 Natura 2000 network

Natura 2000 is the largest network of protected areas in the world. It represent the union of the core and secondary areas for protection for rare and threatened species and habitat in Europe. The network is formed by: i. Special Protection Areas (SPAs), under Birds Directive (79/409/CEE); ii. Sites of Community Importance (SCIs) and Special Areas of Conservation (SACs), under Habitat Directive (92/43/CEE).

In Italy, 19% of lands and 13% of national sea waters are part of this network. In order to evaluate the status of Natura 2000 sites for the protection of *Morimus funereus*, the map below was produced. The analysed area was selected since it contain most of the observation data used previously in this work (1.5). The data from Emilia-Romagna and Veneto regions were removed, since they were only one point per region.

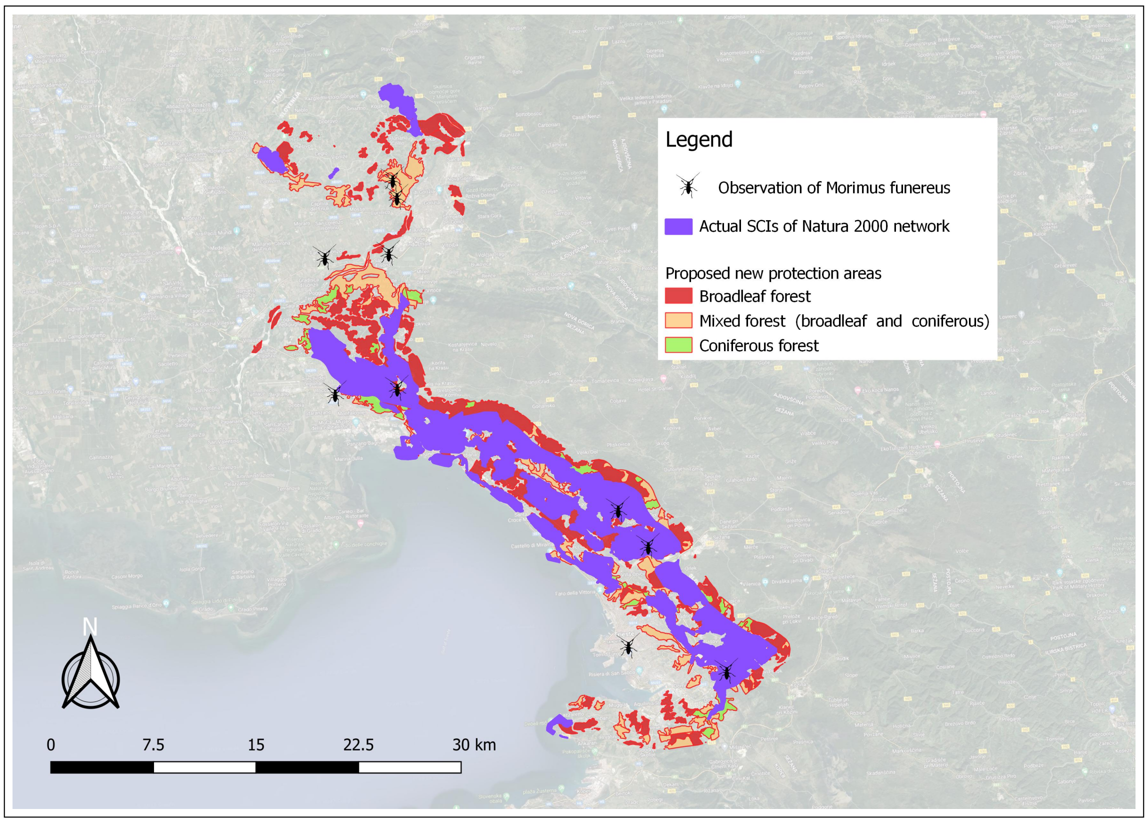


Figure 23: Proposal of integrative areas to Natura 2000 Network. In purple, the actual SCIs in Friuli-Venezia-Giulia region (NW Italy). For the proposed new area, forest is divided by type, as legend show. Observation points of the species are indicated too.

5.1 Proposal of a new protected area

There are sightings of Morimus funereus only in Friuli Venezia Giulia, Veneto, and Emilia Romagna. Since the last two regions cited have only one sighting each, it was decided to place the potential protected area in Friuli Venezia Giulia.

First, suitable habitats for the species were identified through the Corine Land Cover database . The selected sub-categories (third level of CLC) were graphically merged (i.e. by color), based on the species' preferences, obtaining three categories: i. broad-leaved forests (in green), ii. mixed conifer and broad-leaved forests (in yellow), iii. conifer forests (in red). Only suitable habitats within a radius of 5 km from the sightings were selected (given the species' low dispersal capacity). The new protected area was chosen within the provinces of Gorizia and Trieste. The main reason is the highest concentration of observation of the species. Moreover, the great overlap of different core areas could allow individual flow between the populations, despite the low dispersal ability of the species.

Given the presence of high number of M. funereus samples in the provinces of Gorizia and Trieste, this area was chosen because the overlapping core areas could allow for gene flow and/or individuals between presumed populations, despite the species' maximum dispersal ability of 2 km (usually 400-500 m). Given the species' good tolerance for anthropogenic disturbance, as evidenced by sightings in urban areas, an absolute degree of protection would be excessive in this case.

Considerations on urban and peri-urban areas
The great urbanization level of the area could be seen as an obstacle, but some studies on urban ecology show a great potential for conservation of saproxylic insects. European urban parks could host different saproxylic species, including some of high conservation interest (Carpaneto et al., 2015). At national level, in Italy this theory was tested on different species (e.g. *Cerambyx cerdo, Osmoderma eremita, Lucanus cervus, Lucanus tetraodon*) (Carpaneto et al., 2015). Considering the highly similarity in terms of life cycle and ecological needs, in this theoretical protected area, the results of these works were considered adapted for *M. funereus*.

Although the urban green areas management in Italy, like in the rest of Europe, does not include any biological conservation plan for the entomofauna, the implementation of few simple actions could positively affect the xylophagous community. The rural areas do not commonly present old trees, since they are removed by commercial forestry management. Otherwise, in urban landscapes these are maintained more often in city parks, for different reasons: i. cultural and aesthetic value, ii. allow a natural shadow and coolness space, iii. low value nor interest in timber exploitation (Carpaneto et al., 2015). It is important even to remember the public danger risk (Carpaneto, Mazziotta, Coletti, Luiselli, & Audisio, 2010). These, in addition to the maintenance of public safety, have to be considered in theorizing a future conservation area for the species in urban and peri-urban areas.

The proposal is therefore to annex the areas highlighted in the legend as "Protected Areas" to the SCIs already present in the area and to regulate the removal of dead wood, standing or on the ground, in these areas unless it threatens public safety. Regarding old standing trees in city area, colonized by saproxylic species or supposed to be in future, some tweaks could be easily applied, taking some of the management solutions proposed by Carpaneto et al., 2010:

i. Reducing cut of secondary branches, in order to allow the maintenance of microclimatic conditions and shadowing (both for insects and citizens);

ii. Avoid the dead wood (largest branches and trunks) removal, to permit a stable colonization of the species;

iii. Insert metal ropes and other mechanical supports, to hold unstable dying/unhealthy trees;

iv. Maintain clean the areas around the trees of interest, in particular in the hollows of the bark.

Dead wood stockpiles
Furthermore, in the outer sites, log piles could be positioned along new transects within the areas in order to allow an effective monitoring and to have permanent dead wood stations. To best fit the role of structural sustain of *M. funereus*' population, the wood piles will be selected under the instruction proposed by Hardersen et al., 2017a:

Variables	Characteristics
Single elements (trunks/branches)	- Diameter =13-45 cm - Length = 60 cm circa
Log piles	- At least one log with diameter >30 cm - Height = 2 - 4 layers
Wood source	- Dominant native tree species - To prefer *Fagus* spp., *Quercus* spp. or *Carpinus betulus* - If not freshly cut, obtain wood from tree fallen in the same year

Table 6: Basic characteristics of permanent log piles for the proposed protected area (text above for references)

The final integrative areas are not well connected in this proposal, especially in deeply urbanized area. This new protected area would further connect the network of SCIs already present in the area, offering greater protection and increasing the number of ecological corridors not only for *M. funereus* but also for other threatened species present in these areas. Since it is not possible to estimate the availability of creation of a ecological corridor just from the maps, it is important to take it into account. Suitable corridors for the species are needed in as much as an extension of the protected area, but they need to be planned with on-field analysis.

The total area to be designated as a protected area is 116 km^2, while its perimeter is 842 kilometers. The measures proposed within this area should be sufficient to maintain *M. funereus* populations in good condition, as one of the biggest threats to its survival is the removal of dead wood. At the same time it will allow areas closer to or within urban settlements to not have an extreme protection regime that could interfere with their current economic/recreational use.

6 LIFE project

Created in 1992, the LIFE programme is the EU's financing instrument for environment and climate action. Since it was founded, the programme has co-financed more then 6500 projects, divided by five phases (the sixth started in 2021).
The results of a web search of LIFE projects are here shown (LIFE Public Database - March 2023). These are all the actual projects, founded by the EU programme, which involves the conservation of *Morimus funereus*. For each presented project the objectives and the results (if available) are briefly explained.

6.1 LIFE ROsalia

The project "**Conservation of saproxylic beetles in the Carpathians**", also referred to as LIFE ROsalia, is conducted in Putna Vrancea (Eastern Carpathians, Romania). The general focus of this project was to enhance the ecological and conservation status knowledge of five different species of saproxylic beetles: *Rosalia alpina*, *Osmoderma eremita*, *Cerambyx cerdo*, *Morimus funereus* and *Lucanus cervus*.

Specific objectives:

- to increase the connectivity between patches of old-growth forests from Romanian Carpathians by creating 22 stepping-stone habitats in Putna-Vrancea Natura 2000 site, suitable for five priority and non-priority saproxylic beetles
- to increase the understanding of the role and ecosystem service provided by the saproxylic beetles' communities and associated habitats for biodiversity and forest resilience and strengthening the involvement of stakeholders and the local communities in the conservation of these species in Romania
- to update the knowledge regarding concrete conservation of priority and non-priority protected saproxylic beetles among stakeholders from the project area and Romania by actively transferring the knowledge and replicating the techniques demonstrated during the project
- to create and legally bind a national action plan for saproxylic beetles (*Rosalia alpina, Osmoderma eremita, Cerambyx cerdo, Morimus funereus* and *Lucanus cervus*) as a method to unlock the use of concrete conservation of saproxylic species at the national level in the medium and long term

Final results haven't been published yet. On the official website of the project some materials and publications are available (*https://liferosalia.ro*).

LIFE ROsalia was approved by the EU Commission in December 2019. It was funded for a total of 2,943,428 € euro, of which 2,207,571 € of European co-financing (75% of eligible costs). The five year project started on September 1st 2020 and ended on May 31st 2025.

6.2 LIFE MIPP

The LIFE project "Monitoring of insects with public participation", abbreviated as MIPP, was conducted in the Lombardy region, Italy. The aims of this project are based on the assumption that Italy lacks monitoring standards to estimate changes in population sizes, threat levels and conservation status. Moreover, MIPP is based on enhancing knowledge of the public about the Natura 2000 network, Habitat Directive, monitoring and saproxylic insects. Starting from this, wildlife data were collected through Citizen Science using the web and a dedicated app.

Specific objectives:

- to develop an official protocol, approved by the region of Lombardy, based on the methods that have been implemented to monitor populations of insects listed in annexes II and IV of the Habitats Directive (Osmoderma eremita s.l., Lucanus cervus, Cerambyx cerdo, Rosalia alpina and Morimus funereus). Such a protocol is the only reliable standard for estimating population size, threat level and conservation status
- to implement a web-based survey system for the collection of data on insect species (*Lucanus cervus, Rosalia alpina, Cerambyx cerdo, Osmoderma eremita, Lopinga achine, Parnassius apollo, Saga pedo* and *Zerynthia polyxena*) that are included in the annexes of the Habitats Directive
- to inform and educate the general public on different issues, such as the Natura 2000 network, the Habitats Directive, monitoring and saproxylic (dead wood) insects

Results:

- The best monitoring approach, with focus on populations' variation for each species, was selected after different tests in five different areas of Italian Natura 2000 network (SCI and SPA). The detailed description of the methods and results, for each species and area, have been published
- The data from citizen science project were collected, both from website and mobile devices, and validated (with a total of 2308 reports, 73.2%correct) by experts. The most reported species was *L. cervus*, followed by *M. funereus*. Moreover, the data were used to analyse vertical distribution and phenology of the surveyed species

- A total of 227 students meeting and 197 events of different entities were organized along all the project. In addition, 21 seminars for the managers of protected areas, 22 on-field excursions (in the 5 project areas) involved 502 managers and 864 citizens. Communication spread even through different media, including television and radio programs, over one hundred articles on newspapers and websites, on local and national scale. An international workshop was organized for the Regional Observatories for Biodiversity, the Carabinieri Territorial Offices for Biodiversity, the Park Authorities, the Reserves and all those involved in the management of Natura 2000 sites

LIFE MIPP was approved by the EU Commission and funded for a total of 2,734,430 € euro, of which 1,599,906 € of European co-financing (59% of eligible costs). The five year project started on October 1st 2012 and ended on September 30rd 2017.

7 Ecosystem Services and Economic Value

Invertebrates are known for the great value of the ecosystem services they provide. The economical value of their role in nature was estimated around 33 trillion US dollars per year (Costanza et al., 1997). The type of services these organism furnish are various and all necessary, even if not well considered in many older conservation plans.

The value of saproxylic organisms, insect in particular, is well explored. The main ecosystem role is the decomposition of dead wood, allowing the recycle of nutrients and energy (Jonsson, Siitonen, & Stokland, 2012). Natural degradation of wood is a critical process: the number of organism capable of such hard work is very low. Brown, soft and white-rot fungi are the primary organism who act as final metabolizer, but often through insects larvae, such as *Morimus funereus* and other saproxylic coleoptera. This process is necessary to move back carbon from one medium-term stock (i.e. dead wood) to soil, making it available to plants again.

Given the great mechanical modification and degradation of the environment, saproxylic insect assume the role of ecosystem engineers. It is a position discussed by ecologist in the last 20 years (Buse, Ranius, & Assmann, 2008). *Morimus funereus* is one representative species of this group. At the time this report was written, no study about the economical value pf the ecosystem services this cerambycidae provide.

7.1 Direct and Indirect Economic Value

Through a simple web search, the value of a single *M. funereus* specimen can be found. It was not possible to found alive individuals, eggs or larvae, but on different website a dead (prepared in different ways) insect can be found. The prices are considered low, comparing other insect. Taking into account the two example below, no information is provided by the seller about the obtainment of the specimen, expect the country (sometimes the region too) of origin. Even if it is illegal to trade the species without a special certificate or license, it is interesting to observe that some seller neither hide their personal information. The seller of the second following example (Fig. 25), on its profile, mention precisely the city were he come from.

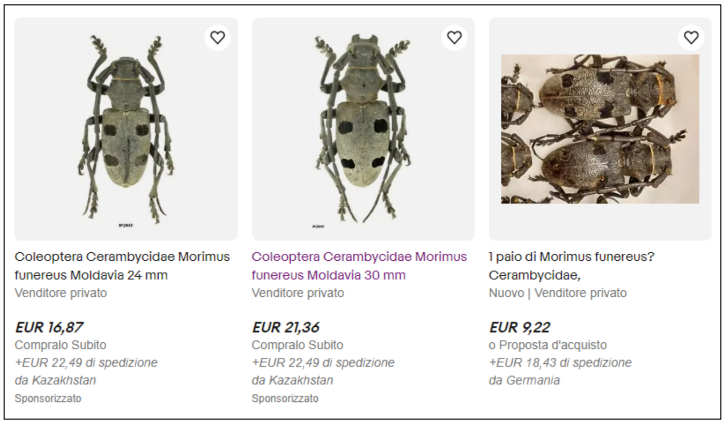


Figure 24: Specimen of *Morimus funereus* that can be found on eBay marketplace (2023)

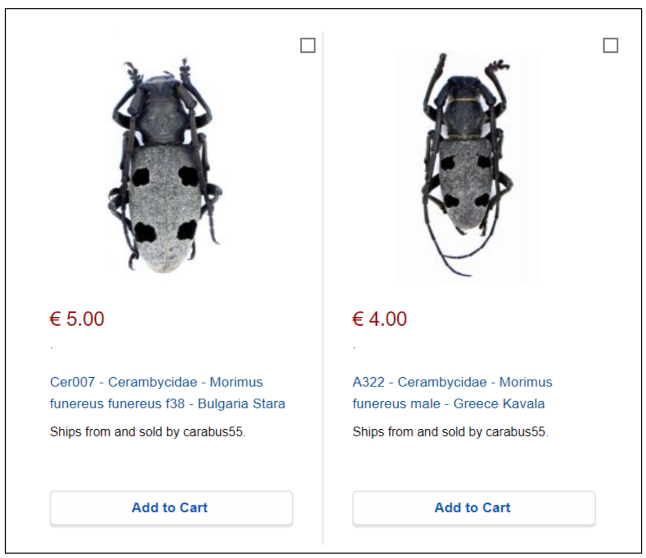


Figure 25: The last specimens available from a seller on *marketplace.insectnet.com*. This cheap specimen is just one of the dozens that this seller shipped in the last year (data from the 2022-2023 selling public records of the website). Even if the individuals come from different place around European continent, the seller is from Veneto (Italy).

8 Public Engagement and Communication

One of the biggest concern of species and habitat protection is related to the knowledge of the problems themselves. An increase of curiosity, consciousness and emotional value in the population could benefit not only the conservation interest by politician and decision makers, but can also bring higher resources and founds for direct action plans. The value of *M. funereus* was discussed and examined in this report, and some authors proposed it as umbrella species for the habitat they inhabit (Chiari et al., 2013). Unfortunately, insects are not the well accepted and charismatic animal. In this last chapter, the critical issue of a communication plan for this species will be listed. After, imagining a theoretical park, some actions will be suggested in order to increase the engagement of the population for this species conservation.

Charisma is necessary to become a star

The main problem linked to the low awareness of insects from the population, is the aesthetics. That's the reason why many conservation projects and environmental protection association (e.g. WWF), which are popular and well known by the public, choose organism that seems more similar to domestic animals or are particularly colorful. Most of the cerambycidae are not colorful, neither remind of a known animal by most. *Morimus funereus* is dark grey, not easy to spot as adult and almost invisible in the rest of life cycle. Moreover, it inhabit a microhabitat not easy access nor attractive to people. Taking into account even its nocturnal activity, to enhance the knowledge about this species and its conservation status, a communication campaign needs to be set as multi-level.

Suggestions and Ideas

Communication at any level, in order to work properly, needs to be specific for a certain target and context. In this case, some action to increase the public interest in this insect conservation are here described, under the point of view of an institutional park. The core of this theoretical project is the graphical redundancy: the image of *M. funereus*, pictures or graphics, needs to be present in everything owned or linked to the park. Since is pretty elusive, most of the people never seen this insect, thus images increase the visitors familiarity and morphological knowledge, which will make easier to communicate the species. Moreover, visual communication is necessary in sight areas and spot of interest for the species (e.g. signs along the paths, flyers). Using the pre-existent paths, some activities linked to the species could be organized. The objective of these activities could be the identification of the species, its ecological role and recognition of its habitat.

M. funereus could become one of the symbol of the park. From this point of view, some knowledge needs to be spread even outside of the structure. The website of the park and every internet realities linked to it, needs to be set in this sense. Information about the park and its activities, conservation of cerambycidae included, needs to be enhanced at any level. A good hint could be increase the attraction through browser interactive games, under the themes of carbon recycle and saproxylic species.

An higher impact could be furnished by a practical interaction of the single (or group of) visitor. In this sense, workshop and other active activities (i.e. games and bioblitz) could enhance the knowledge of the species, its environment and its ecological role. Activities like workshop for families, escape room and nocturnal activities focused on natural recycle of materials life cycle of saproxylic are highly suggested. As integration, the availability of merchandise with *M. funereus* seems to be a good choice, not only communicatively but also could provide an income for conservation and management actions related to the species, inside the park (e.g. see Fig. 26).

A little note need to be made, in order to focus properly the resources in communicate the science, and precisely in conservation biology field. It is important to pay attention on the main message sent by every action: bring interest to protection of the species, not fascination for a mysterious animal. If every action will be set and adapted properly, this communication plan could be extended to other species and microhabitat inside the park, hopefully enhancing the interest for the conservation of the nature.

Figure 26: Example of merchandise based on *Morimus funereus* inspired graphic

References

Audisio, P., Baviera, C., Carpaneto, G., Biscaccianti, A., Battistoni, A., Teofili, C., ... others (2014). Lista rossa iucn dei coleotteri saproxilici italiani.

Bebi, P., Seidl, R., Motta, R., Fuhr, M., Firm, D., Krumm, F., ... Kulakowski, D. (2017). Changes of forest cover and disturbance regimes in the mountain forests of the alps. *Forest ecology and management*, *388*, 43–56.

Bologna, M. A., Bonato, L., Cianferoni, F., Minelli, A., Oliverio, M., Stoch, F., & Zapparoli, M. (2022). Towards the new checklist of the italian fauna. *Biogeographia–The Journal of Integrative Biogeography*, *37*(1).

Buse, J., Ranius, T., & Assmann, T. (2008). An endangered longhorn beetle associated with old oaks and its possible role as an ecosystem engineer. *Conservation Biology*, *22*(2), 329–337.

Campanaro, A., Bardiani, M., Spada, L., Carnevali, L., Montalto, F., Antonini, G., ... Audisio, P. (2011). Linee guida per il monitoraggio e la conservazione dell' entomofauna saproxilica. *Quaderni Conservazione Habitat*, *6*.

Carpaneto, G. M., Baviera, C., Biscaccianti, A. B., Brandmayr, P., Mazzei, A., Mason, F., ... others (2015). A red list of italian saproxylic beetles: taxonomic overview, ecological features and conservation issues (coleoptera). *Fragmenta entomologica*, *47*(2), 53–126.

Carpaneto, G. M., Mazziotta, A., Coletti, G., Luiselli, L., & Audisio, P. (2010). Conflict between insect conservation and public safety: the case study of a saproxylic beetle (osmoderma eremita) in urban parks. *Journal of insect conservation*, *14*, 555–565.

Chiari, S., Bardiani, M., Zauli, A., Hardersen, S., Mason, F., Spada, L., & Campanaro, A. (2013). Monitoring of the saproxylic beetle morimus asper (sulzer, 1776)(coleoptera: Cerambycidae) with freshly cut log piles. *Journal of Insect Conservation*, *17*, 1255–1265.

Copernicus. (2018). *Corine land cover* (Tech. Rep.). https://land.copernicus.eu/pan-european/corine-land-cover: European Environment Agency - European Union.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., ... others (1997). The value of the world's ecosystem services and natural capital. *nature*, *387*(6630), 253–260.

Dojnov, B., Vujčić, Z., Božić, N., Margetić, A., Vujčić, M., Nenadović, V., & Ivanović, J. (2012). Adaptations to captive breeding of the longhorn beetle morimus funereus (coleoptera: Cerambycidae); application on amylase study. *Journal of Insect Conservation*, *16*, 239–247.

Gabor, M., Vrezec, A., & Ratajc, U. (Eds.). (2018, 09). *Dispersal and microhabitat selection of morimus funereus using radio tracking.* doi: 10.13140/RG.2.2.30144.17925

Hardersen, S., Bardiani, M., Chiari, S., Maura, M., Maurizi, E., Roversi, P. F., ... Bologna, M. A. (2017a). Guidelines for the monitoring of morimus asper funereus and morimus asper asper. *Nature Conservation*, *20*, 205-236. Retrieved from https://doi.org/10.3897/natureconservation.20.12676 doi: 10.3897/natureconservation.20.12676

Hardersen, S., Cuccurullo, A., Bardiani, M., Bologna, M., Maura, M., Maurizi, E., ... S., C. (2017b, 04). Monitoring the saproxylic longhorn beetle morimus asper: investigating season, time of the day, dead wood characteristics and odour traps. *Journal of Insect Conservation*, *21*. doi: 10.1007/s10841-017-9970-6

Hedin, J., Isacsson, G., Jonsell, M., & Komonen, A. (2008). Forest fuel piles as ecological traps for saproxylic beetles in oak. *Scandinavian Journal of Forest Research*, *23*(4), 348–357.

Jonsson, B. G., Siitonen, J., & Stokland, J. N. (2012). The value and future of saproxylic diversity.

Jonsson, B. G., Svensson, J., Mikusiński, G., Manton, M., & Angelstam, P. (2019). European union's last intact forest landscapes are at a value chain crossroad between multiple use and intensified wood production. *Forests*, *10*(7). Retrieved from https://www.mdpi.com/1999-4907/10/7/564 doi: 10.3390/f10070564

Leonarduzzi, G., Zandigiacomo, P., & Maurizi, E. (2016). *Applicazione di un nuovo metodo di monitoraggio di morimus asper/funereus, specie protetta dalla direttiva habitat: caso di studio nel parco naturale delle prealpi giulie* (Unpublished master's thesis). Università degli Studi di Udine, Dipartimento di Scienze Agroalimentari, Ambientali e Animali, Udine.

Minelli, A., Ruffo, S., & La Posta, S. e. (1993-1995). *Checklist delle specie della fauna italiana* (No. 1-101). Bologna: Ed. Calderini.

Morris, W., & Doak, D. (2002). Quantitative conservation biology: Theory and practice of population viability analysis. sinauer and associates. *Inc. Publishers, Sunderland, MA*.

Mulsant, É. (1863). *Histoire naturelle des coléoptères de france* (Vol. 5). Maison.

Parisi, V., & Busetto, A. (1992). Scarabaeidae, lucanidae, cerambycidae. *Revisione dei coleotteri presenti nella collezione "A. Leosini". Museo di Storia Naturale, Università di Parma, Parma*.

Pavan, M. (1948a). Sulla durata del ciclo biológico di morimus asper sulz.(col. cerambycidae). *Italian Journal of Zoology*, *15*(1-3), 33–36.

Pavan, M. (1948b). Uovo, stadio ovulare e primo stadio larvale in morimus asper sulz. e lamia textor l.(col. cerambyc). *Italian Journal of Zoology*, *15*(1-3), 49–64.

Polak, S., & Maja, J. (2012). Phenology and mating behaviour of morimus funereus (coleoptera, cerambycidae). *Saproxylic beetles in Europe: monitoring, biology and conservation. Studia Forestalia Slovenica*, *137*, 43–52.

R Core Team. (2022). R: A language and environment for statistical computing [Computer software manual]. Vienna, Austria. Retrieved from https://www.R-project.org/

Romero-Samper, J., & Bahillo, P. (1993). Algunas observaciones sobre la distribución y biología de morimus asper (sulzer, 1776)(coleoptera: Cerambycidae) en la península ibérica. *Boletin de la Asociacion Española de Entomologia*, *17*, 103–122.

Rossi de Gasepris, S. (2016). *Distribution patterns and population analysis of threatened* *longhorn beetles in forest habitats of central italy* (Unpublished doctoral dissertation). Università degli studi Roma Tre.

Rossi de Gasperis, S., Passacantilli, C., Redolfi DeZan, L., & Carpaneto, G. M. (2016, 10). Overwintering ability and habitat preference of morimus asper: a two-year mark-recapture study with implications for conservation and forest management. *Journal of Insect Conservation*, *20*. doi: 10.1007/s10841-016-9913-7

Royle, J. A. (2004). N-mixture models for estimating population size from spatially replicated counts. *Biometrics*, *60*(1), 108–115.

Royle, J. A., & Nichols, J. D. (2003). Estimating abundance from repeated presence–absence data or point counts. *Ecology*, *84*(3), 777–790.

RUFFO, S., & Stoch, F. (2003). Checklist e distribuzione della fauna italiana. memorie del museo civico di storia naturale di verona, series 2, sect. *Scienze della Vita*, *16*.

Sama, G. (1988). *Fauna d'italia*. Bologna: Edizioni Calderini.

Sama, G. (2002). *Atlas of the cerambycidae of europe and mediterranean area. 1: Northern, western, central and eastern europe. british isles and continental europe from france (excl. corsica) to scandinavia and urals.* Zlín, Czech Republic: Vit Kabourek.

Solano, E., Mancini, E., Ciucci, P., Mason, F., Audisio, P., & Antonini, G. (2013). The eu protected taxon morimus funereus mulsant, 1862 (coleoptera: Cerambycidae) and its western palaearctic allies: systematics and conservation outcomes. *Conservation Genetics*, *14*, 683–694.

Stanić, V., Ivanović, J., Janković-Hladni, M., Nenadović, V., & Marović, R. (1985). Feeding habits, behavior, oviposition and longevity of the adult cerambycid beetle morimus asper funereus muls.(col., cerambycidae) under laboratory condition. *Acta Entomologica Jugoslavica*, *21*, 87–94.

Thomas, C. D. (2000). Dispersal and extinction in fragmented landscapes. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *267*(1439), 139–145.

Tikkamäki, T., & Komonen, A. (2011). Estimating population characteristics of two saproxylic beetles: a mark-recapture approach. *Journal of Insect Conservation*, *15*, 401–408.

Trizzino, M., Audisio, P., Bisi, F., Bottacci, A., Campanaro, A., Carpaneto, G., … others (2013). Gli artropodi italiani in direttiva habitat: biologia, ecologia, riconoscimento e monitoraggio. *Quaderni Conservazione Habitat*, *7*, 1–255.

World Conservation Monitoring Centre, W. (1996). *Morimus funereus 1996* (Tech. Rep.). The IUCN Red List of Threatened Species. doi: https://dx.doi.org/10.2305/IUCN.UK.1996.RLTS.T13875A4359886.en