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New records of *Osmoderma eremita* in protected relict forests of Piedmont lowlands (NW Italy) (Coleoptera: Scarabaeidae, Cetoniinae)

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Abstract
Hermit beetle, *Osmoderma eremita* (Scopoli 1763), is a priority species listed in Annexes II and IV of the Habitats Directive, closely linked to mature deciduous trees bearing cavities. As required by articles 11 and 17 of the Directive, in 2021 and 2023 the species was monitored in some lowland wooded areas within the Monviso Park (Piedmont, NW Italy). The monitoring was carried out collecting presence/absence data to inspect population status, phenology and sex ratio, using pheromone baited traps to capture adults during both studies, and searching for exoskeletal remains, larvae and cocoons through the wood mould sampling method in 2021. At the end of the second monitoring period, the presence of the target species was first-time established in all study areas, in addition to other protected saproxylic species records. Planting pollarded trees as well as a forest management attentive to microhabitats are suggested, in order to restore suitable habitat for associated saproxylic beetles and preserve this particularly threatened entomofauna.

Key words: hermit beetle, Habitats Directive, European monitoring protocols, species of community interest, forest management.

Introduction

The Habitats Directive (Council Directive 92/43/EEC) requires all Member States, under articles 11 and 17, to ensure a favourable conservation status for species listed in its Annexes and to produce a related informative report every six years. In this perspective, the Monviso Protected Areas Management Authority started a monitoring program aimed at detecting the actual presence and current situation of the protected saproxylic beetles in some wooded areas of own territorially competence.

One of the species included in the monitoring was *Osmoderma eremita* (Scopoli 1763), commonly known as the hermit beetle. This saproxylic chafer (Scarabaeidae: Cetoniinae) is listed in Annex II as a priority species requiring the designation of Special Areas of Conservation and in Annex IV as a species in need of strict protection.

The monitoring of *O. eremita* was conducted in two periods: summer 2021 and summer 2023. The first research was intended as a knowledge base on which to compare future results, while the second is a continuation of the pilot monitoring. Both studies involved the collection of presence/absence data in order to determine population estimates, evaluate seasonal trends (phenology), and establish the sex ratio. An entomological contribution is also critically analysed, in which several inconsistencies appear, both in reference to *O. eremita* and in reference to other taxa. Having found a population in an area outside a protected site, we recommend the inclusion of this area within the current Special Area of Conservation, effectively modifying its surface.

In addition to the target species, during field activity, further species of conservation interest, assessed in various IUCN extinction risk categories of the Red List of Italian Saproxylic Beetles (Audisio et al. 2014), were found.

Below are the results of the monitoring of *O. eremita* in the protected areas of Monviso Park, inspecting its population status and phenology. Suggestions are also given for both maintaining and improving the condition of the populations and, for each area, the critical issues encountered during monitoring are reported.

Material and methods

Target species

The species studied is *Osmoderma eremita*, a large obligate saproxylic scarab beetle endemic to Europe and associated with hollow trees in old-growth broadleaf woodlands. Larvae develop in at least two years in living trees with large cavities, containing wood mould derived from the activity of non-pathogenic heartwood decay fungi (Nieto et al. 2010). The following year, larvae transform into pupae in spring and emerge as adults in summer, usually in July and early August. Adults live for a maximum of about one month and normally do not survive after the arrival of autumn (Ranius & Hedin 2001; Ranius et al. 2005; Maurizi et al. 2017). Males attract females for mating by emitting a pheromone with the characteristic smell of fermented fruit, used also as a territorial signal and as a kairomone by other saproxylic predatory beetles (Larsson et al. 2003; Svensson et al. 2004, 2009).

O. eremita has not only been found in forests, but also in unusual habitats such as open or semi-open agricultural landscapes and urban green areas (Oleksa 2009; Audisio et al. 2014), while host tree species seem to be basically not important (Nieto et al. 2010). Furthermore, rather than in logs (felled trunks) or snags (standing dead trees), it is found in hollow trees still alive and with a canopy providing a suitable hosting abiotic environment with stable temperature, pH and humidity (Müller et al. 2014).

This very specific microhabitat type resulted in *O. eremita* being listed in both Habitats Directive Annexes II and IV and assessed in the IUCN Red Lists of Saproxylic Beetles as "Near Threatened" (NT) at the European level (Nieto & Alexander 2010) and as "Vulnerable" (VU) at the Italian level (Audisio et al. 2014). It is also considered an indicator of saproxylic beetle richness and a valuable umbrella, flagship and keystone species for the community inhabiting its same environment (Ranius 2002; Jönsson et al. 2004; Oleksa 2009).

Study areas

The research was carried out in three protected areas under the management of the Monviso Park Authority, all located in the lowlands of central southern Piedmont, north western Italy (Fig. 1). All areas were Natura 2000 sites, selected as Sites of Community Importance (SCIs) and/or designated as Special Areas of Conservation (SACs): "Bosco del Merlino" SAC, "Parco di Racconigi e Boschi lungo il torrente Maira" SAC, "Boschi e colonie di chirotteri di Staffarda" SCI.

All the study areas were chosen based mainly on the presence of primary habitat and the ecological requirements of the target species, i.e. old-growth broadleaf forest with large hollow trees and dead wood (Bologna et al. 2016). However, given the high level of alteration in lowland forests, we secondarily selected ecotonal habitats, like wood edges and clearings in agricultural landscapes, as *O. eremita* is a not-strictly forest species (Ranius & Nilsson 1997; Oleksa et al. 2007; Maurizi et al. 2017).

- Bosco del Merlino (Merlino Wood), hereafter MW (SAC IT1160010; 44.7974N, 7.716E; 255 m). This relict forest is considered one of the most representative examples of the last lowland oak-hornbeam habitats (Querco-carpinetum) in the entire Po Plain, despite the small extension of the SAC (354 ha). The wooded surface (58 ha) is made up of two cores, the "Big Wood" (Bosco del Merlino) and the "Small Wood" (Bosco della Pica), completely bordered by meadows and arable lands. The woods show fundamental fragments of forest ecological succession, albeit impoverished in biomass and evolutionary and functional value by heavy cutting (IPLA & Regione Piemonte 2017; Ente di Gestione del Parco Monviso 2022a).
- Parco di Racconigi (Racconigi Park), hereafter RP (SAC IT1160011; 44.78N, 7.663E; 260 m). The SAC contains a riparian wooded strip on the banks of the Maira Torrent and the entire Park of the Royal Castle of Racconigi. Within the Park, a relict of the primary lowland forest is preserved, composed of centuries-old specimens of oak (*Quercus robur* Linnaeus 1753) with hornbeam (*Carpinus betulus* Linnaeus 1753) and other large autochthonous and allochthonous trees, while the rest of the Park includes meadows and some wetlands. The whole SAC area extends over 326 ha and is part of an extensive agricultural context that has exploited some of the most fertile lands in Piedmont for centuries (Ente di Gestione del Parco Monviso 2022b).
- Boschi di Staffarda (Staffarda Woods), hereafter SW (SCI IT1160041; 44.718N, 7.438E; 265 m). The SCI (666 ha) includes woodlands representing some of the few remnants of lowland forest in Piedmont, consisting of extensive oak-hornbeam wood and a lush undergrowth. Despite deforestation and heavy anthropic disturbance over centuries, the woods retain dense vegetation. The environment is thus rather humid and ensures the presence of important wet areas for entomofauna (Rastelli & Della Beffa 2007; Comba 2009; Ente di Gestione del Parco Monviso 2021).

Field work

Several monitoring protocols were considered for field research on the target species. In agreement with the Monviso Park Authority, it was decided to mainly use the methodology outlined in the Guidelines for the monitoring of the saproxylic beetles protected in Europe (Carpaneto et al. 2017). This study follows the previous Guidelines (Campanaro et al. 2011) and the Manual of the Italian Institute for Environmental Protection and Research for the monitoring of animal species of community interest (Stoch & Genovesi 2016). The methods described in the current Guidelines are also synthetically reported in the InNat Technical Manual

(Bardiani et al. 2018). The various operational protocols proposed in the above documents differ minimally and have been combined together where sufficient data could not be obtained with a single methodology.

O. eremita adults were mainly sampled by capture with black cross window traps (BCWT), activated with a pheromone attractive bait. BCWT were built following the instructions in Bardiani et al. (2018), while the bait used was a racemic mixture of γ-decalactone (Sigma-Aldrich, USA). To better define the presence of the target species, dead individuals and exoskeletal parts were collected too. In 2021, in addition to trapping, larvae and/or pupal cocoons inside cavities were searched, through the Wood Mould Sampling (WMS) method (Bologna et al. 2016), in particular in areas where BCWT did not attract beetles despite the use of pheromone bait.

BCWT were placed on hollow trees or nearby trees without cavities, hanging them suspended from branches and as close as possible to the trunk at a height of 2-4 m (Maurizi et al. 2017). In 2021 monitoring, trees chosen for trapping were pollarded poplars (*Populus* Linnaeus 1753) and willows (*Salix* Linnaeus 1753), since pollarding favours the formation of cavities by natural fungal decay, in which the preimaginal stages of Cetoniinae develop, concentrated at the rotting wood of the cavity internal wall (Ranius et al. 2005; Sebek et al. 2013). In 2023, in addition to the trees mentioned, oaks (*Quercus* Linnaeus 1753) were selected, because oak is cited as the most important host plant for *O. eremita* and the only species consistently present in most studies (Ranius et al. 2005; Nieto et al. 2010; Chiari et al. 2012; Bologna et al. 2016).

In each area, the number of BCWT was chosen in relation to the potentially suitable sites for the target species: at MW, we used 9 BCWT in 2021 and 10 in 2023; at RP, we set 8 BCWT both in 2021 and 2023; at SW, we placed 9 BCWT in 2021 and 11 in 2023, for a total of 26 BCWT in 2021 and 29 in 2023.

In Italy, the activity period of *O. eremita* is mostly reported from early June to mid-August, with peaks in July. However, most records are usually made from early July to early August (Maurizi et al. 2017). In 2021, the sampling period was from the last decade of June to the first decade of August, while in the second monitoring, the study period was from the middle of June to the first week of August 2023, i.e. eight weeks for both studies. BCWT were checked every two days, three times a week (Monday, Wednesday and Friday), resulting in 24 surveys (Maurizi et al. 2017). These numbers are in agreement with those indicated in literature, which for *O. eremita* provides a minimum of 15 repeats per area (Bardiani et al. 2018).

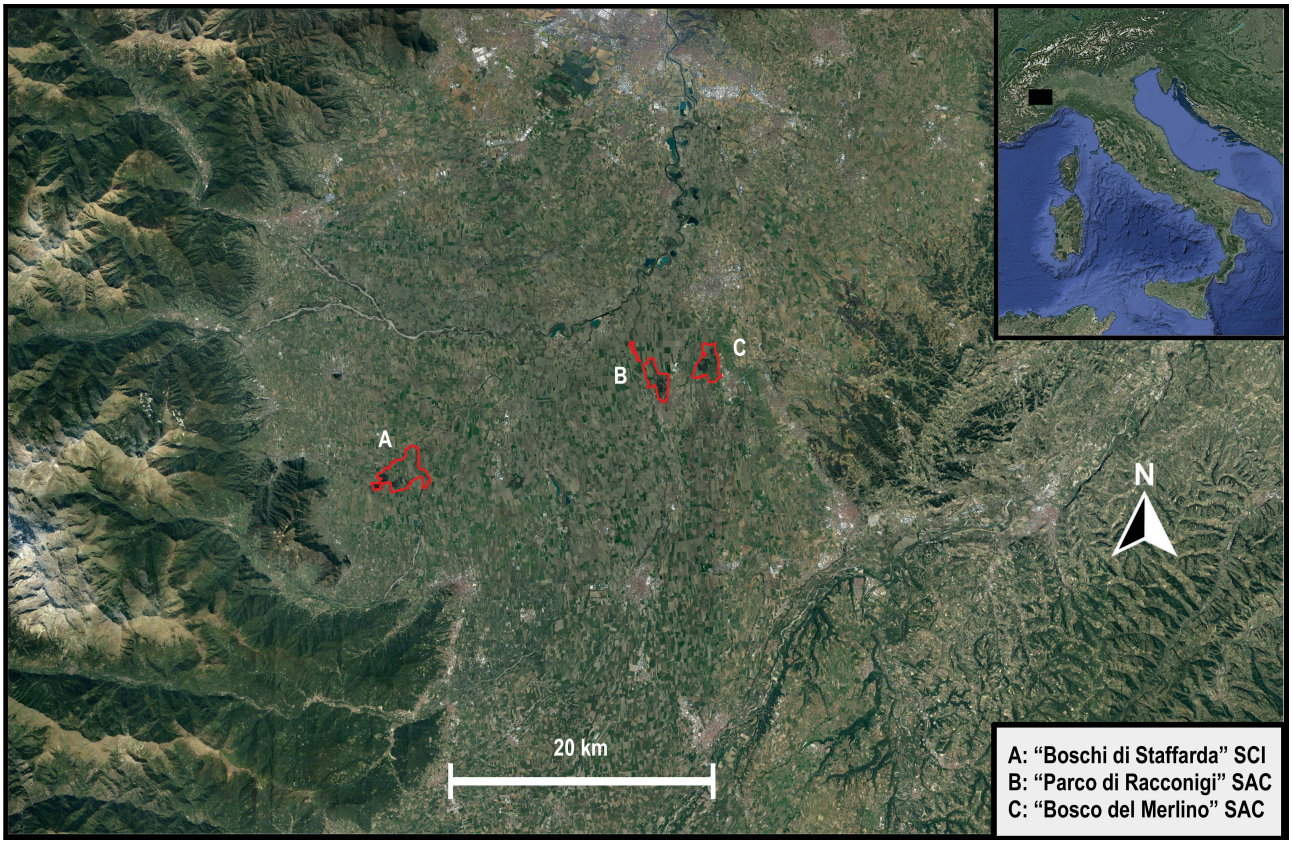

Fig. 1 – Geographical location of the study areas.

When first captured, the sex of each beetle was determined by inspecting the morphological differences of the pronotum: females have a more rounded shaped pronotum than males, which show, unlike to females, a more evident median groove on it (Ballerio et al. 2014; Maurizi et al. 2017). Afterwards, each individual was marked on the elytra by drawing a number (Edding, paint marker 751 white) to avoid overestimates and recounts. No beetle was damaged by the marking procedure.

All data obtained from observations were georeferenced (with obscured geoprivacy) and uploaded to the iNaturalist platform (www.inaturalist.org) to be included in the relevant Monviso Park Authority project (Riserva Mab-UNESCO Monviso).

Data analysis

The monitoring performed in the present study, without an actual CMR (capture-mark-recapture), does not provide an estimate of population abundance but can only be used to locally assess the population trend over the years (Bologna et al. 2016).

We recommend to use the method proposed by Maurizi et al. (2017), which involves the calculation of the average value of the total number of individuals from all surveys, excluding the survey with the lowest number. The average reference value obtained allows for assessing the population trend within a particular area, comparing long-term data collections from each study site and following the fluctuations of the relative populations.

To inspect the phenology and sex ratio of the target species, the seasonal trend was obtained for each single study area, as well as the ratio between males and females, referring to females (f/m).

Results and discussion

A total of 25 *O. eremita* adults were captured, 11 in 2021 and 14 in 2023. During the 2021 study, all beetles collected belonged to RP. In 2023, individuals were found in all three study areas: 2 at MW, 9 at RP and 3 at SW.

The heterogeneity of the data, caused by the multiple disturbing factors characterising both monitoring activities (partial research in 2021 and adverse weather in 2023), does not allow direct comparison (see below). Local differences in the phenology of the target species were expected to occur (Maurizi et al. 2017) and were probably related to 2023 summer variations in temperature and rainfall regimes (ARPA Piemonte 2023). The 2023 sex ratio of the species was strongly female-biassed; this bias towards females is in line with the results of other studies (Chiari et al. 2013a, 2013b; Maurizi et al. 2017) and is probably caused by the capture method through BCWT, which uses the intense attraction of the male pheromone to females (Larsson & Svensson 2009).

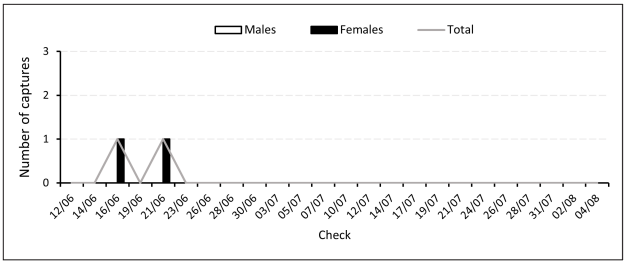

Fig. 2 – Phenology of the target species at MW in the 2023 season.

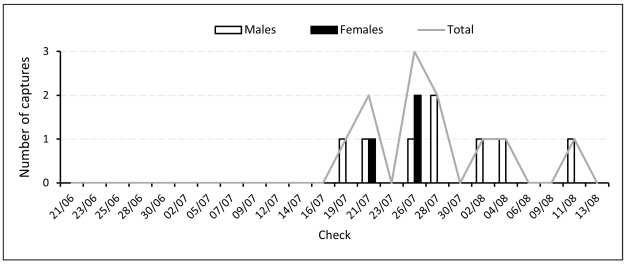

Fig. 3 – Phenology of the target species close RP in the 2021 season.

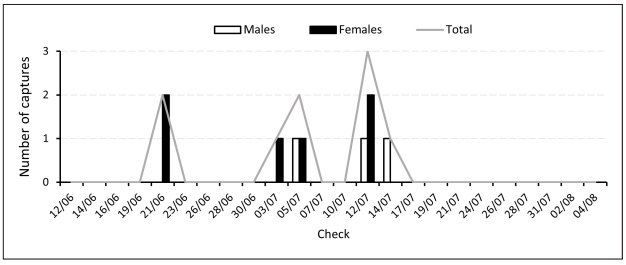

Fig. 4 – Phenology of the target species at RP in the 2023 season.

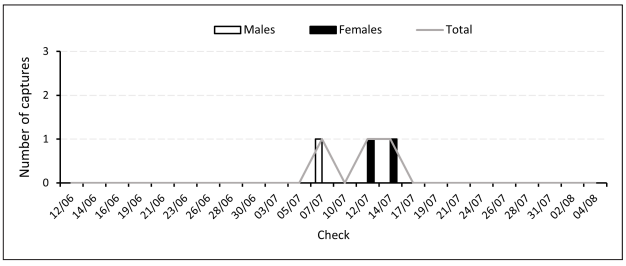

Fig. 5 – Phenology of the target species at SW in the 2023 season.

SAC IT1160010 "Bosco del Merlino"

Number of captures – No adults of *O. eremita* were found in the 2021 survey, while captures of *Protaetia speciosissima* (Scopoli 1786) and *Protaetia cuprea* (Fabricius 1775) were made with BCWT traps. By WMS, larvae of the genera *Protaetia* Burmeister 1842 and *Oxythyrea* Mulsant 1842 were collected in the cavities of willows.

The only literature reference to *O. eremita* for MW cites the findings, between 2002 and 2004, of larvae inside the cavity of *Salix* spp. and exoskeletal remains in a bird pellet and inside decayed *Quercus* spp. (Dutto 2007). However, many critical issues arise in the paper: larvae found in 2004 within hollow willow appear to have actually been collected, but at SW and not at MW (P. Cavazzuti

pers. comm.). Furthermore, the alleged collection of exoskeletal remains in a bird pellet deserves careful reading in order to establish the past presence of *O. eremita* within the SAC. Indeed, although the exoskeletal parts in the pellet demonstrate predation of the target species by a raptor, this may still have occurred outside the protected area. Moreover, the absence of precise georeferencing of the pellet and exoskeletal remains discovery places makes the reliability of the information reported in the paper even more uncertain. For all these reasons, we considered it appropriate to ignore the mentioned data, as it is unverifiable and reasonably doubtful.

In 2023 monitoring, two individuals were captured and one was recaptured. Based on the above literature examination, this is therefore a new record for MW.

Phenology and sex ratio – At MW, the only period of activity was observed in the second decade of June 2023, unusually early for the species (Fig. 2). Out of 2 total individuals, 0 males and 2 females were captured in 2023. This results in a sex ratio consisting exclusively of 2 females (2:0 f/m).

Suggestions for area management – In order to provide a suitable habitat for the new presence of *O. eremita*, we recommend planting specimens of *Quercus* spp., *Salix* spp. and *Populus* spp., these last subjected to pollarding, along sunny ditches present in the SAC. Planting along canals ensures a connection to an irrigation system and an adequate water supply to host plants, while choosing those that are sun-exposed would be ideal for the target species whose larvae development is aided by isolation (Debernardi et al. 2008; Vignon 2015). Planting should be done by ensuring clear spaces (or at most those consisting of low plants) between trees, since *O. eremita* is unable to fly in dense vegetation (Oleksa et al. 2007; Dubois & Vignon 2008; Dubois et al. 2009). Pruning should be continuous during the growth of the planted specimens, limited to what is necessary and performed to preserve cavities (Debernardi et al. 2008).

Although the suggested actions cannot immediately guarantee the presence of *O. eremita* within the SAC, they would at least ensure more habitats for the post-embryonic development of the species, which, if it did not arrive naturally, could be introduced through specific programs (Dubois et al. 2010).

SAC IT1160011 "Parco di Racconigi e Boschi lungo il torrente Maira"

Number of captures – During the 2021 monitoring, 11 specimens of the target species were observed only on the pollarded rows of *Populus* spp. adjacent to the SAC but outside the limits of the protected area. Also, exoskeletal remains were detected inside the cavities of poplars, and larvae were found under the bark near damaged portions of the trunk.

In the SAC, a large tree felling operation was underway. Among the piles of felled logs, large cavities were noticed and evaluated as potentially favourable microhabitats for the presence of *O. eremita* larvae. Despite the altered physicochemical conditions, larvae of *Cetonia* Fabricius 1775 and *Protaetia* Burmeister 1842 were detected inside the cavities by WMS; pupal cocoons of *Protaetia speciosissima* (Scopoli 1786) were also collected.

To safeguard *O. eremita*, we consider it appropriate to implement the surface of the SAC, including the nearby rows of *Populus* spp. This is part of the objectives of this monitoring: identification of areas for the application of additional actions to protect and enhance biodiversity potential and conserve habitats and species listed in the Habitats Directive Annexes.

In the 2023 monitoring, the presence of the target species was confirmed within the perimeter by the finding of nine specimens captured in different *Quercus* spp. and *Populus* spp. areas in the SAC. None of the captured and marked individuals were recaptured.

Phenology and sex ratio – Close at RP, in the 2021 season, the species showed an activity period in the middle of July, with a peak at the end of the same month (Fig. 3). In the next research, the highest number of individuals captured in the 2023 monitoring allowed to highlight a slight peak in seasonal activity, which was concentrated in the first half of July, after a first finding in June (Fig. 4). Since 8 males and 3 females were captured in 2021, the sex ratio value was 1:2,67 f/m (i.e. 1 female for about 3 males). In 2023, out of 9 total individuals, 3 males and 6 females were captured, resulting in a sex ratio of 2:1 f/m (i.e. 2 females for every male). The different sex ratio at RP, unbalanced in favour of males in 2021 and therefore in contrast with the female-biassed ratio of 2023, was due to the inability in 2021 to conduct surveys in the entire Park area.

Suggestions for area management – The presence of the target species within the SAC highlights the importance of maintaining decaying trees, especially in a context that represents a unicum, as in the case of RP. In order to safeguard saproxylic entomofauna of conservation interest, several recommendations are given for actions to both protect fauna and ensure public safety in an area frequented by visitors (Debernardi et al. 2008). We suggest the removal and/or thinning of hedges and shrubs by lowering them to a maximum height of 1 m, thus promoting the creation of a low turf between veteran trees and the formation of natural corridors with the innermost wooded portions. The management of old large trees located in areas used by tourists should include the use of static and dynamic bracing systems to restore crown balance, in order to guarantee public safety (Debernardi et al. 2008). Dead or decaying wood should be managed by constituting standing dead trees: all felled logs should be placed as snags in open and sunny spaces to advance the multi-year development of the larvae inside them (Ente di Gestione dei Parchi Reali 2023a). Finally, informative material should be produced to raise public awareness of the importance of conserving dead wood for the protection of biodiversity (Debernardi et al. 2008; Ente di Gestione dei Parchi Reali 2023b).

SCI IT1160041 "Boschi e colonie di chirotteri di Staffarda"

Number of captures – During the 2021 field work, no target specimens were captured by BCWT. However, exoskeletal remains and a pupal cocoon of a dead individual were found through WMS; both were collected in pollarded *Populus* spp. cavities. Inside hollow *Salix* spp. and *Populus* spp., larvae and cocoons belonging to *Protaetia cuprea* (Fabricius 1775) were found.

The only literature reference to the past presence of *O. eremita* at SW reports preimaginal forms collected in 2004 within a cavity of *Salix* spp.; however, it is not possible to verify whether the finding occurred inside or outside the SAC.

In 2023, three captures were made with BCWT. None of the captured and marked individuals were recaptured.

Phenology and sex ratio – At SW, in the only observed period of activity, a static trend was recorded, between the first and second weeks of July 2023 (Fig. 5). Out of 3 total individuals, 1 male and 2 females were captured in 2023. The resulting sex ratio was 2:1 f/m (i.e. 2 females for 1 male).

Suggestions for area management – As suggested for MW, we recommend planting new specimens of *Quercus* spp., *Populus* spp. and *Salix* spp., these last subjected to pollarding, in particular along the sunny canals that run through the SAC. Continuous pruning of planted trees will lead to the formation of sun-exposed cavities, suitable for the larval development of *O. eremita*, and will ensure the presence of the abiotic characteristics of the microhabitat in which the preimaginal stages of the target species develop (Ranius & Nilsson 1997; Sebek et al. 2013).

Other protected species recorded

We report the finding in all three study areas of *Elater ferrugineus* Linnaeus 1758 (Coleoptera: Elateridae), a species assessed as "Vulnerable" (VU) in the IUCN Red List of Italian Saproxylic Beetles (Audisio et al. 2014). This natural predator of *O. eremita* larvae has been frequently found in BCWT, due to its attraction to pheromone, used as kairomone. Since its occurring is closely related to the prey, it is considered in some monitoring programs a good indicator of the possible presence of *O. eremita* (Svensson et al. 2004; Svensson & Larsson 2008; Larsson & Svensson 2009).

In all areas, BCWT also captured other species evaluated as "Near Threatened" (NT) in Italy (Audisio et al. 2014): *Prionychus ater* (Fabricius 1775) (Coleoptera: Tenebrionidae, Alleculinae), found in all areas, and *Pycnomerus terebrans* (Olivier 1790) (Coleoptera: Zopheridae), found at MW and RP.

Conclusions

At the end of the second monitoring, the presence of *O. eremita* was established in all three study areas. Pilot monitoring captured adults outside RP, in an area close to the SAC, while exoskeletal remains and one pupal cocoon were found at SW. In 2023, compared to the previous study, some adult specimens were found in different or new portions of the study areas: for MW it is a first-time record, for RP a new record within the SAC and for SW a new adult record.

The confirmed presence of the target species now raises the question about its conservation. Therefore, actions should be taken to ensure that the area close to RP, where *O. eremita* was detected, is included in the SAC as soon as possible; in addition, within the Park of the Royal Castle, the macrohabitat frequented by the preimaginal forms should be maintained unchanged. Regarding the other protected areas, urgent forest management intervention is required: planting trees subjected to pollarding, mainly along sun-exposed irrigation canals, will be necessary. This will offer future microhabitats suitable for the larval development, in order to preserve the species at SW and to restore its habitat at MW. These actions are suggested following the tendency of *O. eremita* to prefer sunny sites and to react negatively to the cessation of traditional management of woodlands, which can lead to the disappearance of the species, or otherwise cause damage, according to several studies (Ranius & Nilsson 1997; Dubois & Vignon 2008; Dubois et al. 2009; Oleksa et al. 2007; Vignon 2015; Maurizi et al. 2017).

Besides the target species sampling, the finding of some other saproxylic beetles cited in the Red List risk categories highlights the need for continuous qualitative and quantitative studies focused on this particularly threatened entomofauna (Nieto & Alexander 2010; Audisio et al. 2014), in order to acquire current status of the saproxylic species present in the various wooded environments, and define forest management aimed at protecting this biodiversity.

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