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RELATIONSHIP BETWEEN TREE-RELATED MICROHABITATS AND THE CAPTURES OBTAINED USING DIFFERENT TRAP METHODS FOR LARGE THREATENED SAPROXYLIC BEETLES

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Sabatelli S., Parisi F., Vangi E., Francini S., D'Amico G., Chirici G., Travaglini D., Rignanese D., Muambalo K., Audisio P. - Relationship between tree-related microhabitats and the captures obtained using different trap methods for large threatened saproxylic beetles

Osmoderma eremita and *Cerambyx cerdo* are saproxylic beetle species, included in the IUCN Red List and in the EU/92 Habitats Directive. Their occurrence has been recorded, through appropriate traps, in several localities in Italy, including urban and peri-urban parks, mostly associated with veteran trees.

In this study, traps were tested over 17 veteran oak trees in the Castelporziano Presidential Estate (Latium, Rome province, central Italy) and the abundance of sampled saproxylic beetles was related to the growing stock volume (GSV) and the abundance of microhabitats. Moreover, we compared three different trapping methods: a trap designed to monitor *C. cerdo* (CC), and two traps designed for monitoring *O. eremita*, i.e., the Black Cross Window Trap (BCWT) and the Black Bottle Traps (BBT).

We found that larger trees hosted a great variety of microhabitats, in particular cavities, which abundance was correlated with the number of specimens sampled, especially *O. eremita* species. Both classic traps (i.e., CC traps and BCWT) and the herein-introduced BBT variants were effective for capturing large saproxylic beetles.

In this work, we underline the importance of the preservation of veteran trees to the occurrence of threatened saproxylic beetles, and we contributed to (i) extending general knowledge of the habitat preferences of saproxylic beetles and (ii) improving new cost-effective trapping system variants.

KEY WORDS: *Osmoderma eremita*, *Cerambyx cerdo*, IUCN threatened species, Tree-related Microhabitat, urban and peri-urban areas, veteran trees.

INTRODUCTION

Woodlands and trees located in urban and peri-urban areas provide a great variety of benefits and services for human well-being, such as carbon sequestration, water retention, mitigation of the urban heat island effect, and biodiversity conservation (FAO, 2016). For these reasons, there is an increasing interest in urban and peri-urban forestry and its relevance in terms of biodiversity (ULYSHEN, 2018).

In recent years, veteran trees have seen a significant increase in scientific interest (MÜLLER *et al*., 2013, LINDENMAYER and LAURANCE, 2017, PARISI *et al*., 2018, 2019, 2023, WETHERBEE *et al*., 2021). They are characterized by remarkable size in terms of both diameter and height, a well-developed crown, large lateral branches, and, in general, extreme longevity (LINDENMAYER and LAURANCE, 2017, LARRIEU *et al*., 2018). Veteran trees can be even relatively young, but what distinguishes them from large or small young trees is that they can accommodate a wide range of Tree-related Microhabitats, which represent an ecological niche for wildlife (STOKLAND *et al*., 2012). In urbanized areas, large trees can act as "biodiversity hotspots" (LINDENMAYER and LAURANCE, 2017), since they can support populations of high conservation priority species (CARPANETO *et al*., 2010, AUDISIO *et al*., 2014). These species may find suitable conditions for their survival in urban parks, thanks to the fact that, in those areas, most of their natural predators lack, and large trees are

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not harvested for timber production (Carpaneto *et al.*, 2010, Audisio *et al.*, 2014).

Massive trees, especially free-growing ones, are known to be the only hosts of several saproxylic species. The survival of saproxylic species depends on the availability and distribution of woody resources for their life cycle, closely related to decaying and dead wood, and microhabitats (Parisi *et al.*, 2020a, 2021, Casula *et al.*, 2021). In Norway, Wetherbee *et al.* (2021) found that the abundance of saproxylic beetles around veteran oaks was higher than around young ones, while Müller *et al.* (2013), in a beech forest in Germany, discovered that veteran hollow trees were richer in Red-listed species, compared to trees without any microhabitat.

Some of the saproxylic species most threatened in Europe are *Osmoderma eremita* (Scopoli, 1763) (Coleoptera: Scarabaeidae, Cetoniinae), *Elater ferrugineus* Linnaeus, 1758 (Elateridae), and *Cerambyx cerdo* (Linnaeus, 1758) (Cerambycidae). These species are included in IUCN European Red List with Near Threatened status (Cálix *et al.*, 2018) and - except *E. ferrugineus* – they are listed in the Annexes II and IV of the EU Habitats Directive (European Commission, 1992).

The hermit beetle (*O. eremita*) is well-known to have a poor dispersal ability and the availability of suitable trees is a limiting factor for its survival and reproduction since each tree can act as a habitat that can host a small population (Ranius, 2006, Audisio *et al.*, 2014). In Italy, Ranius *et al.* (2005) recorded the presence of *O. eremita* in several localities, mostly associated with deciduous and evergreen oaks (especially *Quercus robur* L., *Q. ilex* L.), hollow trees, and wood mould. Along the Tyrrhenian coast, the species has been recorded in Castelfusano and Castelporziano, two peri-urban reserves near Rome (Ranius *et al.*, 2005). Carpaneto *et al.* (2010), report the presence of hermit beetles for Latium in old-growth forests and in isolated hollow three and even in urban parks. The most southern reports in the region are for the Special Area of Conservations (SACs) "Sugherete di S. Vito e Valle Marina" (IT6040005) and "Monti Ausoni meridionali (IT6040006)" (Chiari *et al.*, 2013). Lenzi *et al.* (2022) report *O. eremita* in the Circeo State Forest (province of Latina).

Different trapping methods can be used to sample endangered saproxylic beetles, like *O. eremita*, and they can be divided into passive and active traps (Chiari *et al.*, 2013). A passive trap type is the Pitfall Trap (PT), composed of a jar placed inside the cavity of hollow trees, with no chemical lures inside (Campanaro *et al.*, 2011). Among active methods, the main type of traps used for *O. eremita* are pheromone traps such as Black Cross Window Traps (BCWT) and Interception Air Trap (IAT). According to some authors, e.g., Campanaro *et al.* (2011), Chiari *et al.* (2013), BCWT is more efficient than IAT in catching the hermit beetle. Moreover, according to Maurizi *et al.* (2017), BCWT performs even better than PT in Italy, chiefly in the southern part of the hermit beetle geographic range, where the population density is usually very low.

Concerning *Cerambyx cerdo*, many trapping methods have been proposed, such as the usage of artificial sap, baited traps, visual surveys of adults on trunks, and the collection of remains of the species. Redolfi De Zan *et al.* (2017) proposed using baited traps as the standard monitoring method for *C. cerdo*. These traps can be baited with a mixture of red wine, beer, and mashed banana, or a mixture of red wine, white wine, and sugar. Redolfi De Zan *et al.* (2017) found that the latter type of lure performed better in catching *C. cerdo*.

Since veteran trees and microhabitats are a major concern for forest biodiversity in the urban context (Parisi et al., 2022a, Bütler et al., 2013), this paper deals with their importance in the Castelporziano Presidential Estate (Rome) to the occurrence of the hermit beetle and the great capricorn beetle (*C. cerdo*).

This study has three aims. First, to analyse the relationships of the amount of sampled beetles with (i) the growing stock volume and (ii) the abundance of Tree-related Microhabitats. Second, to test the differences of capture methods (i.e., BCWT and baited traps) in sampling large threatened saproxylic beetles. Third, to compare the capture of Black Cross Window Traps (BCWT) and Black Bottle Traps (BBT), a new trap model introduced in this study, in sampling *O. eremita*.

MATERIALS AND METHODS

Study area

The field research was carried out in Castelporziano Presidential Estate (41°44′40″N 12°23′59″E), a peri-urban natural reserve, located 20 km south-west of Rome, along the Tyrrhenian coast of Latium (Central Italy) (Fig. I).

The reserve extends to 6039 ha, with altitudes between sea level and 85 m. More than 2000 ha are covered by a lowland forest composed of evergreen and deciduous oaks (*Quercus ilex* L., *Q. suber* L., *Q. cerris* L., *Q. robur* L., *Q. frainetto* Ten.) and hygrophilous species (*Populus* spp., *Fraxinus* spp.). Thus, Castelporziano is one of the major remnants of the original flat deciduous oak forest that occupied the coastal zone of the region (Moretti *et al.*, 2015).

The climate of Castelporziano was classified as typical Mediterranean: precipitations are concentrated in the cold season with an annual mean of 740 mm, while the summer season is dry, with high temperatures (25°C on average) coexisting with scarce precipitation (Manes *et al.*, 1997).

The reserve is an important site of conservation value, thanks to the high level of biodiversity it hosts, the richness of both plant species and wildlife, and numerous temporary and permanent pools with natural wetland vegetation (Moretti *et al.*, 2015). Since 2000, Castelporziano has been part of the Natura 2000 network (SCI IT6030027 "Castelporziano coastal strip", SCI IT6030028 "Castelporziano hygrophilous oaks", SPA IT6030084 "Castel Porziano Presidential estate") according to Birds Directive (Directive 79/409/EEC). Moreover, since 2017, both SCIs have been designated as Special Areas of Conservation (SAC).

17 veteran trees belonging to the species *Quercus ilex* L. (seven trees) and *Q. robur* L. (10 trees) were selected to record the occurrence of endangered saproxylic beetles (Fig. I), and for their large diameters (≥50cm) and dimensions through an accurate inspection. Indeed, they are "habitat trees" since they host a great variety of microhabitats (for the selection of trees with high ecological value see Mason and Zapponi, 2018). Consequently, these trees seemed suitable for the presence and survival of large saproxylic beetles (Fig. II, 1, 2).

potentially present in the collecting container. Every trap was mapped by GPS and marked by a label with its number.

The window flight traps used for *O. eremita* were the Black Cross Window Trap (**BCWT**), and a variant of BCWT, called Black Bottle Trap (**BBT**). The BCWT is composed of two crossed plastic panels connected to a funnel and a bottle, which contains a microtube filled with 1.2 ml of pheromone (a racemic mixture of γ-decalatone, catalog no. W236004, Sigma-Aldrich, USA) (Svensson and Larsson, 2008) (Fig. II, 3). We installed four BCWT on four veteran trees, placed them on the

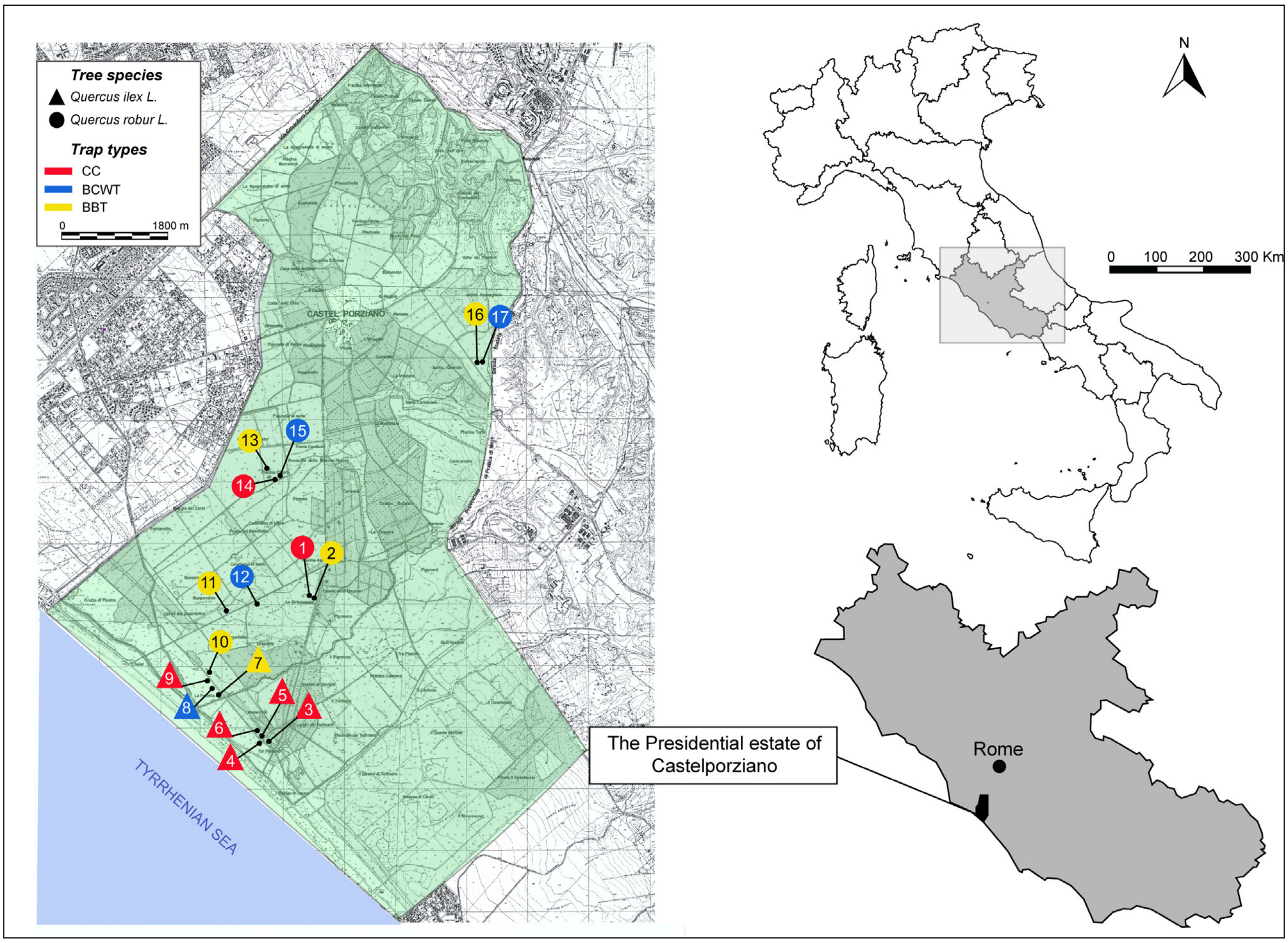


Fig. I - Location of the 17 veteran trees in the Castelporziano Presidential Estate (Rome, Italy), selected in our study. The shape of the labels refers to the tree species, while the colours refer to the trap types. The red label represents the locations of the traps used for *Cerambyx cerdo* (CC); the blue label represents the Black cross windows traps (BCWT) and the yellow one represents the black bottle traps (BBT).

Beetles sampling

Following the MIPP (LIFE11 NAT/IT/000252) guidelines for monitoring saproxylic beetles (Mason et al., 2015, Maurizi et al., 2017, Redolfi De Zan et al., 2017), we used two trapping methods to monitor Osmoderma eremita and Cerambyx cerdo (Table 1). Moreover, we used the Black Bottle Traps (BBT), a new trap model introduced in this study, in sampling O. eremita.

The sampling was carried out by two operators checking the traps during the summer season in 2017 and 2018, from the beginning of June to the end of September, every other day to avoid the death of the organisms

trunk, and suspended them from tree branches at 2-3 m from the ground. The BBT is a cost-effective and simple variant of the BCWT, herein used for the first time. The trap is composed of an upside-down black plastic bottle with a hole connected to a collecting container filled with pheromones. We installed these types of traps on the other six veteran trees and placed them on the trunk at 2-3 m from the ground (Fig. II, 4).

Eventually, the traps explicitly used for *C. cerdo* (**CC**) consist of two containers joined together but separated internally by a net. The lower bottle is filled with a mixture of white wine, red wine, and sugar, which at-

Table 1 - Summary of tree species and trap type used in this study, with relative IDs and coordinates (in WGS84 coordinate system). Black Cross Window Trap (BCWT), Black Bottle Trap (BBT), *Cerambyx cerdo* traps (CC).

TREE ID	***TREE SPECIES***	***TRAP TYPE***	***COORDINATES***
1	*Quercus robur*	CC	41°42'08"N 12°23'53"E
2	*Quercus robur*	BBT	41°42'08"N 12°23'52"E
3	*Quercus ilex*	CC	41°40'55"N 12°23'24"E
4	*Quercus ilex*	CC	41°40'55"N 12°23'18"E
5	*Quercus ilex*	CC	41°40'59"N 12°23'16"E
6	*Quercus ilex*	CC	41°41'05"N 12°23'06"E
7	*Quercus ilex*	BBT	41°41'18"N 12°22'50"E
8	*Quercus ilex*	BCWT	41°41'22"N 12°22'45"E
9	*Quercus ilex*	CC	41°41'23"N 12°22'45"E
10	*Quercus robur*	BBT	41°41'27"N 12°22'42"E
11	*Quercus robur*	BBT	41°41'03"N 12°22'50"E
12	*Quercus robur*	BCWT	41°42'10"N 12°23'15"E
13	*Quercus robur*	BBT	41°43'07"N 12°23'27"E
14	*Quercus robur*	CC	41°43'06"N 12°23'28"E
15	*Quercus robur*	BCWT	41°43'06"N 12°23'29"E
16	*Quercus robur*	BBT	41°44'19"N 12°25'41"E
17	*Quercus robur*	BCWT	41°44'19"N 12°25'43"E

tracts the great capricorn beetle, while the upper bottle is covered so that the sampled organism cannot fly away. The CC model refers to the baited traps reported by Redolfi De Zan *et al*., 2017. These traps were installed on seven veteran trees at 10 meters from the ground in 2017 but started the following year (Fig. II, 5).

SURVEY OF FOREST STRUCTURE

To link the occurrence of threatened beetles to structural features, we measured the diameter at breast height (DBH) with a tree calliper, and heights (H) through a vertex hypsometer (Laser Vertex Hypsometer, Haglöf, Sweden), of the 17 selected veteran trees. The growing stock volume (GSV) was estimated for each tree from diameter at breast height (DBH) and total height (H), using double-entry volume equations (Tabacchi et al., 2011).

We also surveyed Tree-related Microhabitats on living trees, carefully examining the trunk from the ground to the crown and following the hierarchical classification proposed by Kraus *et al*. (2016), integrated with the one proposed by Larrieu *et al*. (2018), and recording microhabitat abundance of every veteran tree. These are primarily cavities, injuries, crown deadwood, excrescences, fruiting bodies of fungi, mould, epiphytic and epixylic structures, and exudates (Larrieu *et al*., 2018).

RESULTS

During the sampling period, 50 specimens of saproxylic beetles were collected (Table 2). Overall, we caught 36 individuals of *Osmoderma eremita* through BWCT and BBT. Through CC traps, we sampled six fragments of *Cerambyx cerdo* in the first monitoring year because traps only started in 2018 when we sampled eight adults (overall, 14 records).

Through BBT a higher number of beetles were sampled compared to BCWT: indeed, BBT caught 21 specimens of *O. eremita*, while in BCWT they were just 15.

Fig. III shows the difference in the number of *O. eremita* specimens sampled with BBT and BCWT. Median values of the number of organisms sampled with BBT and BCWT are, respectively, 1.5 and 4. On average, the trapping of the two methods used is comparable.

As a result of the structural survey, we found that the average DBH was 209 cm, the average H was 18 m, and the average GSV was 37 m^3.

Furthermore, a total of 1509 tree-related Microhabitats were censused. Table 3 lists the abundances for each type of microhabitat, recorded on *Q. ilex* and *Q. robur*.

Overall, the most abundant microhabitat types were cavities (microhabitat code **CV**, see Table 3), which represent 77% of the total amount of microhabitats censused, followed by injuries (**IN**, 6%), deformations and growth forms (**GR**, 5%) and deadwood in the crown (**DE**, 5%). Microhabitats formed by bark shelters and pockets (**BA**, 2%), and other structures, such as sap and resins run, microsoil (**OT**, 2%) were the least common at all, and only one group of microhabitats was completely absent, namely **NE** (vertebrate and invertebrate nests).

There was a difference in the abundances of microhabitats concerning tree species: on pedunculate oak trees, a total of 1225 microhabitats were found, while on holm oak, only 284 (Table 3). On both species, the most abun-

Fig. II - Details of oak (*Quercus robur*) veteran trees (1, 2); a Black Cross Window Trap (BCWT) (3); a Black Bottle Trap (BBT) (4); a trap specific for *Cerambyx cerdo* (CC) (5); an adult of *C. cerdo* (6); an adult of *Osmoderma eremita* (7) (photographs by F. Parisi and S. Sabatelli).

Table 2 – Diameter (DBH), volume (GSV), and records of saproxylic species sampled on each tree. The captures of *O. eremita* were carried out in 2017 and 2018. *C. cerdo* was sampled only in 2018.

Tree ID	DBH (cm)	GSV (m^3)	Trap type	*Osmoderma eremita*	*Cerambyx cerdo*
1	190	24.05	CC		3
2	180	22.82	BBT	1	
3	68	3.75	CC		0
4	75	3.12	CC		0
5	63	2.62	CC		3
6	55	2.03	CC		2
7	201	23.53	BBT	0	
8	190	18.31	BCWT	0	
9	250	37.61	CC		2
10	216	35.35	BBT	0	
11	330	67.59	BBT	14	
12	380	123.71	BCWT	5	
13	290	67.89	BBT	4	
14	260	41.96	CC		4
15	320	65.12	BCWT	7	
16	300	68.20	BBT	2	
17	190	32.17	BCWT	3	

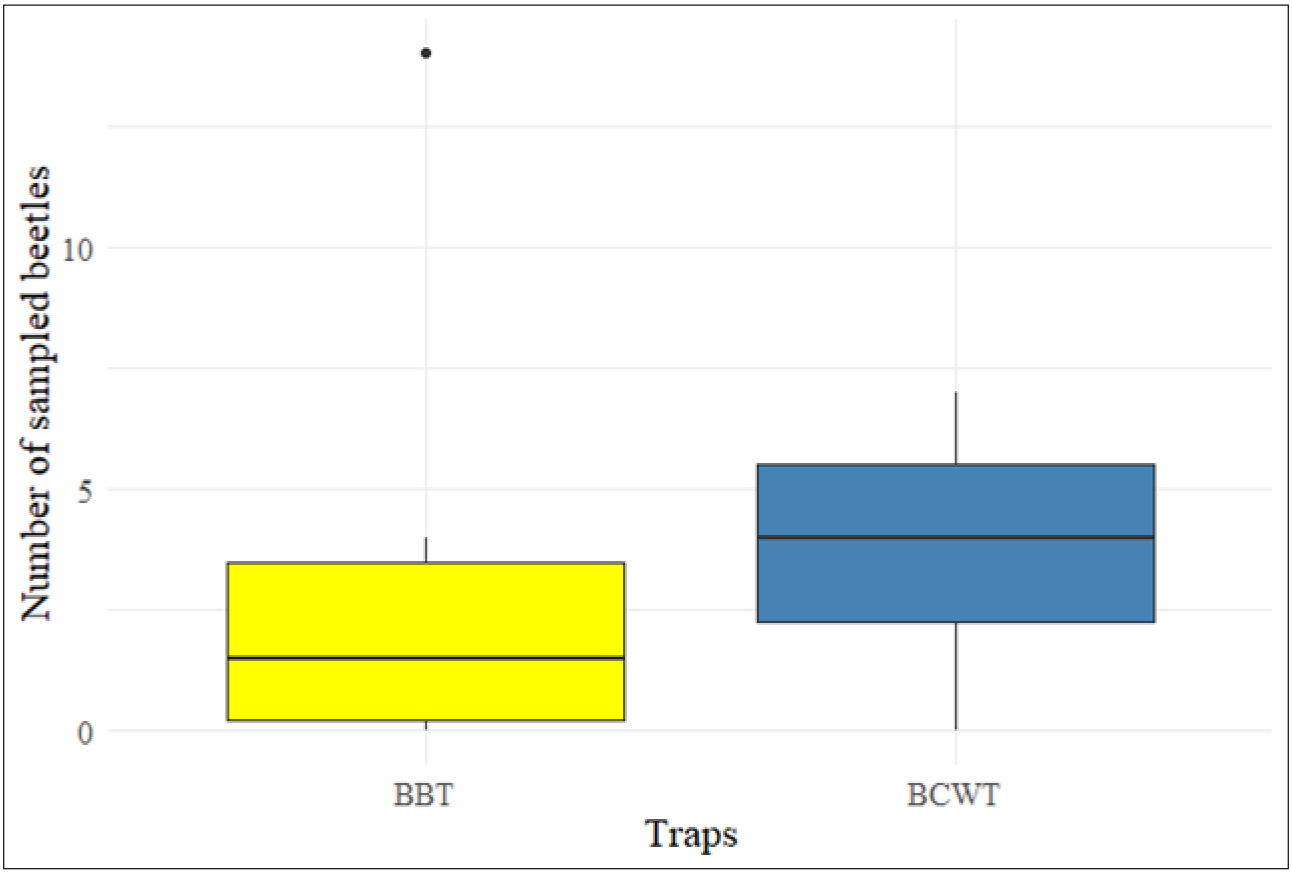
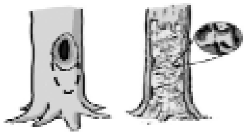
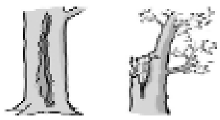
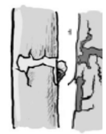
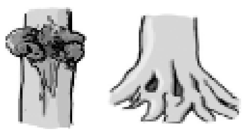
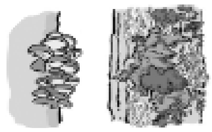
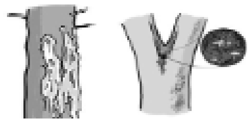


Fig. III - Comparison of the number of *Osmoderma eremita* specimens sampled with BCWT and BBT (colors used according to Fig. I).

Table 3 – Abundances of each type of microhabitat censused (description and illustrations from Kraus *et al*., 2016 and Larrieu *et al*., 2018).

Microhabitat code	Description	Illustrations	*Quercus ilex* abundance	*Quercus robur* abundance
CV	Cavities (woodpecker cavities, trunk and mould cavities, branch holes, dendrotelms, insect galleries)		183	986
IN	Injuries and wounds (bark loss, exposed sapwood and heartwood, trunk and crown breakage, cracks and scars)		25	69
BA	Bark (shelters, pockets, and coarse bark)		6	20
DE	Deadwood (dead branches, limbs, and crown deadwood)		21	54
GR	Deformation and growth form (root buttress cavities, witches'-broom, water sprout, cankers and burrs)		21	56
EP	Epiphytes (fruiting bodies of fungi, Myxomycetes, crypto- and phanerogams)		16	25
OT	Other (sap and resin flows, microsoil)		12	15

dant microhabitat type was **CV**, which alone represents 80% and 64% of the microhabitats censused on *Q. robur* and *Q. ilex*, respectively. In line with the general trend, on both pedunculate oak and holm oak trees, cavities are followed by **IN** (respectively, 6% and 8%), **GR** (5% and 7%), and **DE** (4% and 7%).

Eventually, we compared the abundance of saproxylic beetles with the GSV and the number of microhabitats found on each tree. Fig. IV shows the number of specimens of saproxylic species sampled on each veteran tree, along with the GSV and the abundance of Tree-related Microhabitats of each tree.

DISCUSSION

The life activity of primary endangered saproxylic species is less dispersive, and they very rarely leave their refuge in rotten deadwood or cavities (e.g., Rukavina *et al*., 2018). In our case, the recaptures of *O. eremita* never occurred. We can hypothesize a certain mobility of the species among the different habitat trees, not necessarily close to each other (Chiari *et al*., 2013).

For this reason, these captured species are probably associated with the veteran tree itself, and the identified environmental variables, such as tree diameter and microhabitats, are unquestionably important for their life. Bouget *et al*. (2012) found that bulky standing veteran oaks are more valuable than thinner trees or even lying trunks. Some studies have also confirmed that the number of species increases with the dimensions of deadwood (Basile *et al*., 2023, Macagno *et al*., 2015, Parisi *et al*., 2020b), and large specimens also host large species of beetles (Brin *et al*., 2011). We can agree with Horák (2017) that saproxylic beetles prefer free-growing veteran trees. These are equally important for other insects, plants, mosses, and also vertebrates, such as birds and bats (Parisi *et al*., 2018).

As the trunk diameter increases, trees can offer a more diverse mosaic of microhabitats, such as large cavities or various stages of wood decomposition (e.g., Asbeck *et al*., 2021, Grossmann *et al*., 2018, Parisi *et al*., 2022b,

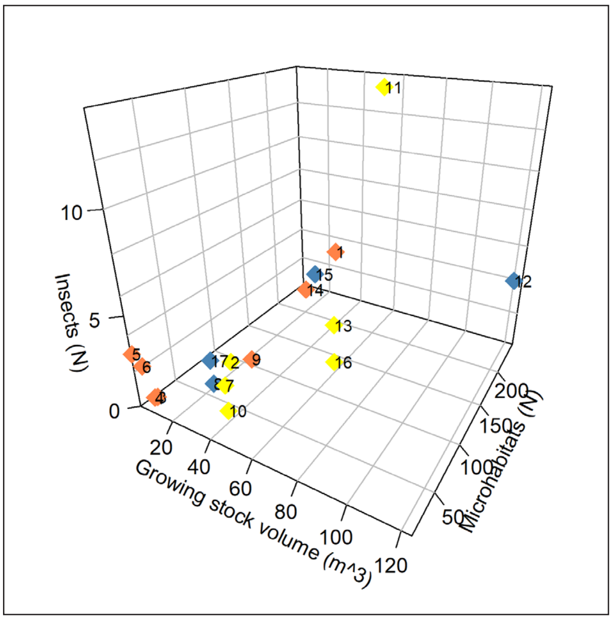


Fig. IV - Abundance of *Osmoderma eremita* (Traps BBT and BCTW) and *Cerambyx cerdo* (CC) specimens sampled, compared to GSV and microhabitat abundance of each veteran trees (numbered) (colors used according to Figg. I and III).

Winter and Möller, 2008). Indeed, we found that larger trees hosted a great abundance of microhabitats (e.g., Tree ID 12, 16, 13, 11, see Fig. IV). The whole veteran tree offers numerous optimal dimensions from branches to strong trunks affected by rot. However, especially for Red List species, one of the most important microhabitats is represented by cavities (Parisi *et al*., 2020a). Generally speaking, the rarest saproxylic species are bound to very thick decaying trunks, typical representatives being old-growth relicts listed by Eckelt *et al*. (2018) for Central Europe. Indeed, in our study, the most abundant Tree-related Microhabitats were cavities (code **CV**), and among all their types, insect galleries were the most common and recurring structures found on oak veteran trees. These are complex systems of holes and chambers created by one or more xylophagous insect species within the trunk (Kraus *et al*., 2016).

This in turn reflects on the abundance of saproxylic beetles. Both BBT and BCWT proved to work efficiently, with a comparable capture abundance. Especially the highest trapping abundance occurred on trees hosting a great number of microhabitats. Indeed, we observed a general relationship among the GSV, the abundance of microhabitats, and the number of specimens sampled, especially of the species *O. eremita* (e.g., Tree ID 11, 15, 12, see Fig. IV), which is closely associated with the occurrence of cavities and hollow trees (Ranius *et al*., 2005). This result is consistent with several other studies, e.g., Parmain and Bouget (2018), Wetherbee *et al*. (2021).

We used BCWT to collect *Osmoderma eremita*, and we investigated the difference in the performances with a herein-introduced variant of BCWT named BBT. As shown in Fig. IV, overall BBT collected more specimens (21) of *O. eremita* on *Q. robur* trees, while BCWT type captured fewer specimens (15). Nevertheless, BCWT showed a slightly higher capability, on average, compared to BBT (Fig. III). Indeed, the high number of specimens captured on some trees (i.e., tree ID 11) allows BBT to be considered a fairly good trapping method, comparable to the classic trap.

While *O. eremita* was the target species for this survey, *Elater ferrugineus* Linnaeus, 1758 (Elateridae) has been observed as a "bonus". Indeed, in the same traps, we also found five adults of *E. ferrugineus*. Having in mind the biology of both species, where *E. ferrugineus* can predate on other species besides the hermit beetles. Differences could support our findings that habitats suitable for the hermit beetle may also host the red click beetle, but all habitats occupied by the red click beetle may not fit for the hermit beetle (Oleksa *et al*., 2015). We considered this species since it is a natural predator of *O. eremita* larvae. Indeed, the species uses γ-decalactone as a kairomone to locate its prey, which is the same pheromone emitted by *O. eremita* males to attract conspecific females (Svensson and Larsson, 2008). In agreement with Redolfi De Zan *et al*. (2017), we used a mixture of red wine, white wine, and sugar to catch *Cerambyx cerdo* and the method proved to perform well since CC traps caught the great capricorn beetle even on small trees with few microhabitats (e.g., Tree ID 5, 6, see Fig. IV). Nevertheless, larger trees with a great abundance of microhabitats hosted a larger number of specimens (e.g., Tree ID 14, 1, 9, see Fig. IV), confirming the general trend. Capricorn beetles prefer *Q. robur* of large dimensions. However, they are not directly linked to the cavities or other large tree-related microhabitats, and can thus also live on *Q. ilex* on which there can be few microhabitats (e.g., Tree ID 5, 6, 9, see Fig. IV).

The natural dying of trees is important for species that need the gradual decay of the entire tree where habitat niches develop. Typical inhabitants of recently dead trunks and branches are the families Buprestidae and Cerambycidae, of medium-decayed deadwood e.g., the family Elateridae, and of the very advanced phase of wood decomposition, the rotted wood inside the cavities hosts representatives of several families, e.g., Scarabaeidae. Of crucial importance, each species of saproxylic beetle has specific demands for the dimensions of deadwood. Thus, the preservation of veteran trees is a major concern in Europe and needs to be part of an international strategy focused on the conservation of cultural landscapes and their key structures (Campanaro and Parisi, 2021, Zapponi *et al*., 2017), at different spatial scales, ranging from the smallest scale, e.g., retention of a single tree, to wider ones, e.g., the conservation of entire forest stands (Casula *et al*., 2021).

Oaks are considered to be the most valuable trees for saproxylic beetles. This is likely due to the different characteristics of deadwood and the rate of senescence of the involved tree species. The tree species studied have been the most common deciduous trees in Mediterranean forests. Pedunculate oak (*Q. robur*) and holm oak (*Q. ilex*) are the most common solitary tree species found in our study, as well as in many areas of Europe (Parmain and Bouget, 2018). In general, we observed a difference in both size and abundance of microhabitats between the two species: GSV of holm oak trees (e.g., ID 3, 4, 5, 6) was smaller than GSV of pedunculate oak (e.g., ID 12, 16, 13) (see Table 2). This trend in turn reflects the occurrence of Tree-related Microhabitats (Fig. IV).

However, to achieve a better comprehension of the actual differences between the traps used, also to the ecological link between Tree-related Microhabitats and saproxylic beetles, there is a need for: i) a larger study area, a higher number of sampled veteran trees (Parisi, 2022), and ii) a higher number of observations. Indeed, it should be considered that large saproxylic beetles have a multi-annual larval stage, thus iv) a longer sampling period is also needed.

Our results stress the need for further studies and monitoring activities, to better understand the role of veteran trees in urban and peri-urban areas as key elements for the conservation of threatened species.

CONCLUSIONS

Our work confirms that veteran trees are key structures in the urban and peri-urban landscape, where they act as "habitat trees" for large threatened saproxylic beetles. Indeed, their volume and abundance of microhabitats proved to be crucial for *Osmoderma eremita* and *Cerambyx cerdo*, which are included in the EU Habitats Directive and in the IUCN Red List.

The capability of BCWT traps, the BBT, and CC traps to sample specimens of the *O. eremita* and *C. cerdo*, was tested to the growing stock volume and the abundance of Tree-related Microhabitats of veteran trees. The results confirm the effectiveness of classic traps (i.e., CC traps and BCWT traps) for capturing large saproxylic beetles. Moreover, the BBT variant proved to be correct and comparable to classic trapping methods. Thus, further research is needed to improve and validate the herein-presented capture system, which, in turn, is simple, economic, and efficient.

Given a limited number of extensive and well-structured field studies of both species in this part of Europe, the data presented can contribute to directing further studies and extending general knowledge of the habitat preferences of these species.

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