Nature Conservation 20: 205–236 (2017)
doi: 10.3897/natureconservation.20.12676
http://natureconservation.pensoft.net

CONSERVATION IN PRACTICE

A peer-reviewed open-access journal
Nature Conservation
Launched to accelerate biodiversity conservation

Guidelines for the monitoring of *Morimus asper funereus* and *Morimus asper asper*

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Academic editor: *G.M. Carpaneto* | Received 12 March 2017 | Accepted 5 July 2017 | Published 28 August 2017

http://zoobank.org/A2620AE2-4C99-44C1-B151-1D0ACB8D2C45

Citation: Hardersen S, Bardiani M, Chiari S, Maura M, Maurizi E, Roversi PF, Mason F, Bologna MA (2017) Guidelines for the monitoring of *Morimus asper funereus* and *Morimus asper asper*. In: Carpaneto GM, Audisio P, Bologna MA, Roversi PF, Mason F (Eds) Guidelines for the Monitoring of the Saproxylic Beetles protected in Europe. Nature Conservation 20: 205–236. https://doi.org/10.3897/natureconservation.20.12676

Abstract

Morimus asper is a morphologically variable longhorn beetle that occurs in large parts of southern and central Europe. Although this saproxylic beetle is widespread in old-growth forests or well-structured woodlands, its populations are currently threatened by forest practices, such as the removal of wood (branches and logs). *Morimus funereus* is considered a valid species by some authors and is included in Annex II of the Habitats Directive. However, a recent molecular study found that all European and Turkish populations should be referred to a single species, *M. asper*. In this paper, the monitoring methods proposed for *M. asper* (*sensu lato*) in the various European countries are reviewed and the research carried out in Italy, which was aimed at developing guidelines for its monitoring, is presented. The experiments conducted, mainly with log piles built from freshly cut wood, investigated, amongst other things, the importance of wood type, diameter of logs and age of wood for the number of individuals observed. Based on these results and on a literature review, a detailed monitoring method for *M. asper* is proposed here, together with a discussion on its constraints, spatial validity and possible interferences. In order to facilitate the assessment of the conservation status of populations of *M. asper* and to allow for comparisons between populations and over time, a method for the calculation of a reference value, based on the monitoring method, is also presented.

Keywords
Habitats Directive, saproxylic beetles, Coleoptera, Cerambycidae, monitoring methods, forest biodiversity

Introduction

Morimus Brullé, 1832 is a genus of the family Cerambycidae with a complex taxonomic situation. *Morimus funereus* Mulsant, 1863 and *M. asper* (Sulzer, 1776), once considered distinct species, are now believed to belong to a single, genetically and morphologically variable species, *M. asper* (e.g. Sama and Löbl 2010, Sama and Rapuzzi 2011, Solano et al. 2013, Danilevsky 2015). Populations of this species typically live in old-growth forests or well-structured woodlands. *Morimus funereus* is included in Annex II of the Habitats Directive (Council Directive 92/43/EEC). The Habitats Directive provides that Member States prepare, every six years, a report on the conservation status of the species listed in the Annexes. In order to address this obligation, the Life Project "Monitoring of insects with public participation" (LIFE11 NAT/IT/000252) (hereafter, MIPP) conducted experimental fieldwork to develop a standardised method for monitoring of the saproxylic beetle species of the project: *Osmoderma eremita* (hermit beetle, Scarabaeidae), *Lucanus cervus* (European stag beetle, Lucanidae), *Cerambyx cerdo* (great capricorn beetle, Cerambycidae), *Rosalia alpina* (rosalia longicorn, Cerambycidae), *Morimus asper/funereus* (morimus longicorn, Cerambycidae).

The present paper is part of a special issue on the monitoring of saproxylic beetles protected in Europe and is dedicated to *Morimus asper/funereus*. Therefore, it starts with a comprehensive revision of the current knowledge on systematics, distribution, ecology, ethology and conservation. The review is followed by a detailed account of the fieldwork carried out during the project and concludes with a description of the proposed monitoring method.

Systematics and Distribution

Morimus Brullé, 1832 is a genus of the large beetle family Cerambycidae, subfamily Lamiinae. The genera *Morimus* and *Herophila* are the only European representatives of the tribe Phrissomini (Breuning, 1942), whose main distinguishing feature is the fact that they have reduced hindwings and are unable to fly. Until some years ago, the European populations of the genus *Morimus* were divided into five species, *M. asper* (Sulzer, 1776), *M. funereus* Mulsant, 1863, *M. orientalis* Reitter, 1894, *M. verecundus* (Faldermann, 1836) and *M. ganglbaueri* Reitter, 1894, based exclusively on morphological characters. However, many transitional forms exist amongst these taxa, are difficult to ascribe to one of the above mentioned species and their taxonomic position was often unclear. The different taxa, which are mostly geographical forms, differ from one another in certain morphological traits such as the size and distribution of the granules on the elytra and the colour pattern of the elytra, in particular the background colour and the shape and size of the black spots (Stanić et al. 1985, Sama 1988, 2002, Koren 2010, Sama and Löbl 2010, Danilevsky 2013). Recently, several authors have started considering *M. asper* and *M. funereus* as two subspecies of the same species (e.g. Sama and Löbl 2010, Sama and Rapuzzi 2011, Solano et al. 2013, Danilevsky 2015, Danilevsky et al. 2016). In particular, a molecular study based on COI and ITS2 gene sequences (Solano et al. 2013), found that all European and Turkish populations should be referred to a single, genetically and morphologically variable species which, according to the rules of the International Code of Zoological Nomenclature (http://www.iczn.org/iczn/index.jsp) should be named *M. asper* (Sulzer, 1776). All other taxa merit an intraspecific rank and are simple colour morphs or subspecies. Subsequent studies (Danilevsky 2015, Danilevsky et al. 2016) further complicated the taxonomic situation of the genus by describing a new species from Slovakia (*M. gabzdili* Danilevsky, 2015), a new subspecies of *M. asper* from Greece and a new subspecies of *M. verecundus* from Bulgaria (Danilevsky et al. 2016). Further molecular studies are needed to clarify the complicated taxonomic situation of the genus *Morimus*.

Morimus funereus was included in Annex II of the Habitats Directive with the taxonomic rank of a species, according to the literature of the time (Dajoz 1976). In light of new systematic findings, this protection should also be extended to *M. asper* (*sensu lato*).

When evaluating the systematic position of the taxon *funereus*, it is important to consider that it was described from south-eastern France (Mulsant 1863) and consequently it cannot be a valid name for the eastern European form which probably needs a different name. The taxonomic problems of the genus *Morimus* cannot be resolved in this paper, but need a systematic revision which will also have important implications for the conservation of this taxon.

Here, we consider the two taxa *asper* and *funereus* as subspecies of *M. asper*, as described by many authors (Sama and Löbl 2010, Sama and Rapuzzi 2011, Solano et al. 2013, Danilevsky 2015, Danilevsky et al. 2016). These occur respectively in western (*M. asper asper*) and eastern (*M. asper funereus*) Europe, while *M. asper ganglbaueri* is interpreted as a transitional form between these subspecies due to genetic introgression (Rapuzzi, in preparation). *Morimus asper* (*sensu lato*) is widely distributed in southern and central Europe, from the Iberian Peninsula to European Turkey and occurs in: Albania, Austria, Bosnia and Herzegovina, Bulgaria, Corsica, Croatia, Czech Republic, European part of Turkey, French mainland, Greek mainland, Hungary, Italian mainland, Montenegro, Republic of Macedonia, Republic of Moldova, Romania, San Marino, Sardinia, Serbia, Sicily, Slovakia, Slovenia, Spanish mainland and Switzerland (http://www.fauna-eu.org, Bringmann 1996, Gnjatović and Žikić 2010, Vrezec et al. 2012). The exact distribution of the two major subspecies (*M. asper asper* and *M. asper funereus*) is not clear because of the unreliability of many literature data. However, the distribution of the two subspecies in Italy is quite clear: *M. asper asper* occurs in all regions, including the major islands (only a few known sites in Sardinia). *Morimus asper funereus* was recorded only for the karst area in Friuli-Venezia Giulia (Trieste and southern Gorizia

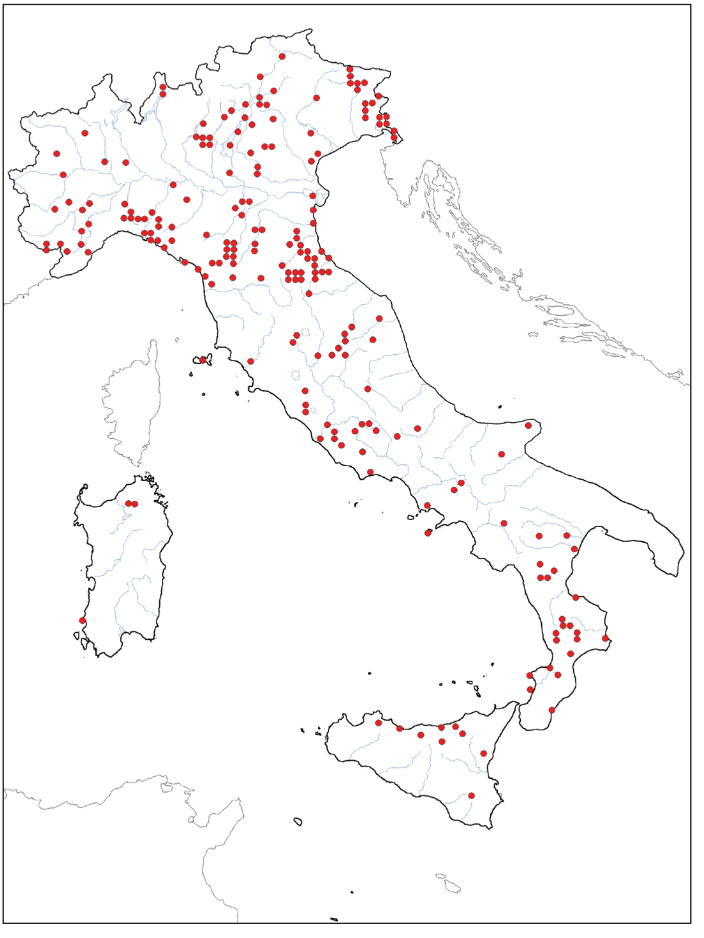

Figure 1. Distribution map of *M. asper* in Italy (Sama 2007).

provinces). The transitional form *ganglbaueri* occurs in Italy from the Tagliamento River to the Karst area of Friuli-Venezia Giulia (P. Rapuzzi, pers. com. 2016). The distribution of *M. asper* in Italy is given in Figure 1 (Sama 2007).

Morphology

The egg of *M. asper* has an ivory colour and measures about 4.5 × 1.2–1.6 mm, with the surface of the chorion consisting of a relief with stellate structures (Romero-Samper and Bahillo 1993). The development of the larval stages is typical for holometabolous insects, as the various instars do not vary greatly in shape, but only differ in body size. The larva has a typical morphology for saproxylophagous longhorn beetles: the colour is white and fleshy, the head is sclerified, with very small antennae and the body is legless (Pavan 1948a, 1948b, Romero-Samper and Bahillo 1993) (Figure 2). The newly hatched larvae measure about 5 mm in length but, at the last larval stage, can reach up to 60 mm (Romero-Samper and Bahillo 1993). The pupa is exarate, i.e. has free appendages (Pavan 1948a, 1948b) and initially is milk white, but darkens as the metamorphosis progresses (Romero-Samper and Bahillo 1993).

Adults (Figure 3) measure 15–40 mm in length (Parisi and Busetto 1992) and have an elongated-oval body. The elytra are fused together, have a grainy look and are typically dark grey or opaque black. Each elytron bears two black spots but these can be almost invisible in individuals with a very dark background colour. As mentioned above, this background colour differs amongst the various taxa and forms throughout the range of the species.

A conspicuous sexual dimorphism exists in the antennal length of *M. asper*, as in many other longhorn beetles. Male antennae can measure up to 7.5 cm, exceeding the length of the body and are much longer than in females (Parisi and Busetto 1992) (Figure 4). In a recent study, Rossi de Gasperis (2015) showed that the length of the antennae varies greatly amongst males from the same population and that males with longer antennae mate more frequently. The same study also revealed a sexual dimorphism in the pronotum length as well as in the width and length of the elytra, with males allocating more resources to the development of the anterior portion of the body, while females invest more in the posterior part of the body, where the reproductive system is located.

Identification and comparison with similar taxa

Morimus asper is chromatically variable throughout its range and the two subspecies *asper* and *funereus* are distinguished by different background colours (Figures 3 and 4): darker, almost black in *M. asper asper* and light grey with four very obvious spots in *M. asper funereus*. This chromatic variability is accompanied by slight differences in the micro sculpture of the elytra, in particular in the shape and size of the granules that cover their surface. *Morimus asper* can be easily distinguished from all other Italian longhorn beetles, with the only exception being *Herophila tristis* (Linnaeus, 1767) (Figure 5A) which belongs to the Phrissomini tribe as *M. asper* and *Lamia textor* (Linnaeus, 1758) (Figure 5B), of the Lamiini tribe. Compared to *H. tristis*, *M. asper* is generally longer (*M. asper*: 16–38 mm; *H. tristis*: 13–26 mm). Another important feature is the background colour which, in *H. tristis*, is clearly brown rather than black or grey. Further distinguishing characters are antennae and legs which are thicker and shorter in *H. tristis*. In *M. asper*, the first antennal segment is shorter than the third whereas, in *H. tristis*, it is longer or as long as the third segment.

Lamia textor is relatively rare in Italy and can be distinguished from *M. asper* by some characters that can be difficult to observe in the field, particularly in females. One such character is the absence of wings in *M. asper* (well developed in *L. textor*) and another is

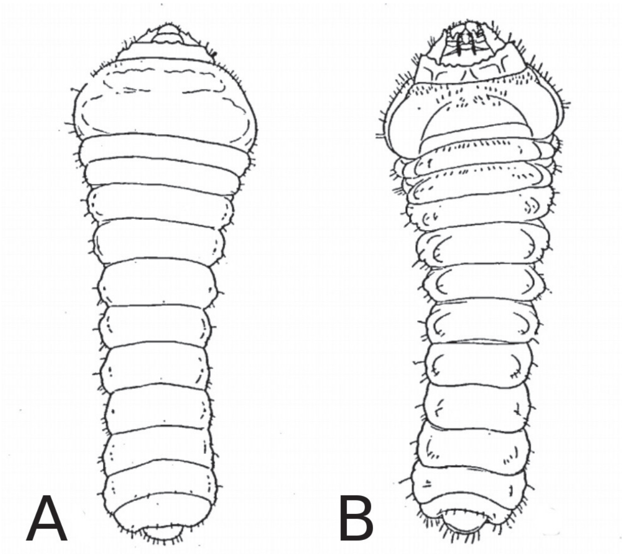

Figure 2. A freshly hatched larva of *Morimus asper asper*: **A** dorsal view **B** ventral view (Pavan 1948b).

that the first antennomere is shorter than the third in *M. asper*. In contrast, in *L. textor*, the first antennomere is as long or longer than the third and the circular keel of the first antennomere is well marked and complete whereas, in *M. asper*, this keel is less marked and incomplete. A lobe on the outer side of the mesotibia is well marked in *M. asper* but less visible in *L. textor* (Picard 1929, Porta 1932). Further differences relate to the form of the elytra; in *M. asper*, they are more humped and the humeral callus is more projecting (despite the fact that *M. asper* is wingless). Furthermore, the granules are more marked on the entire surface of the elytra of *M. asper* and smaller on the apical third (especially in the ssp. *funereus* where they are partly covered by bristles), but are always clearly visible. In contrast, in *L. textor*, granules are clearly visible only in the fore half of the elytra and tend to fade towards the rear and, in the apical area, form a slight and indistinct roughness. A final character concerns the surface of the elytra of *L. textor* which is much flatter, often showing a pattern of white specks that can be almost invisible.

Ecology

Habitat

Morimus asper is a silvicolous, xylophagous and saproxylic species, its main habitat being deciduous and mixed forests (Jurc et al. 2008, Carpaneto et al. 2015). The species lives mainly in old-growth forests or well-structured woodlands, with a medium-high density of dead wood (Trizzino et al. 2013, Bărbuceanu et al. 2015). In forests, rich in deadwood, such as in the well-studied site of Bosco della Fontana (Mantova, northern Italy), abundant populations can be present (Hardersen et al. 2017). According to the literature, *M. asper* mainly lives in deciduous forests, often dominated by oaks (*Quercus* spp.)

Figure 3. *Morimus asper funereus* (Photo by Kajetan Kravos).

or by beech (*Fagus sylvatica*) (López-Vaamonde et al. 1993, Romero-Samper and Bahillo 1993, Bărbuceanu et al. 2015, Rossi de Gasperis et al. 2016). Even though the preferred habitats are mature forests, populations of this beetle are often found in coppiced stands, characterised by the presence of old stumps and decaying wood on the ground (Cerretti 2008). For many areas of Europe, a preference for beech forests has been reported; for example in Slovenia (Jurc et al. 2008) and in the Iberian Peninsula (López-Vaamonde et al. 1993, Romero-Samper and Bahillo 1993). In Bulgaria, *M. asper* is much more common in the mountain beech forests than in the plains and hills, where it is mainly found in the more humid woodlands, such as riparian forests (Anonymous 2015).

Morimus asper is flightless and has a very limited dispersal capacity when compared to other longhorn beetles (Luce 1996, Bărbuceanu et al. 2015) and its populations are often fragmented. As a consequence, there are numerous habitats that are suitable for this species but are not colonised by it (Bărbuceanu et al. 2015). The research, carried out during the MIPP project, also confirmed this observation for some of the areas investigated in Italy. Rossi de Gasperis et al. (2016) marked 727 individuals in different areas of central Italy and only reported dispersal in 13 adults, with distances covered varying between 20 and 451 metres.

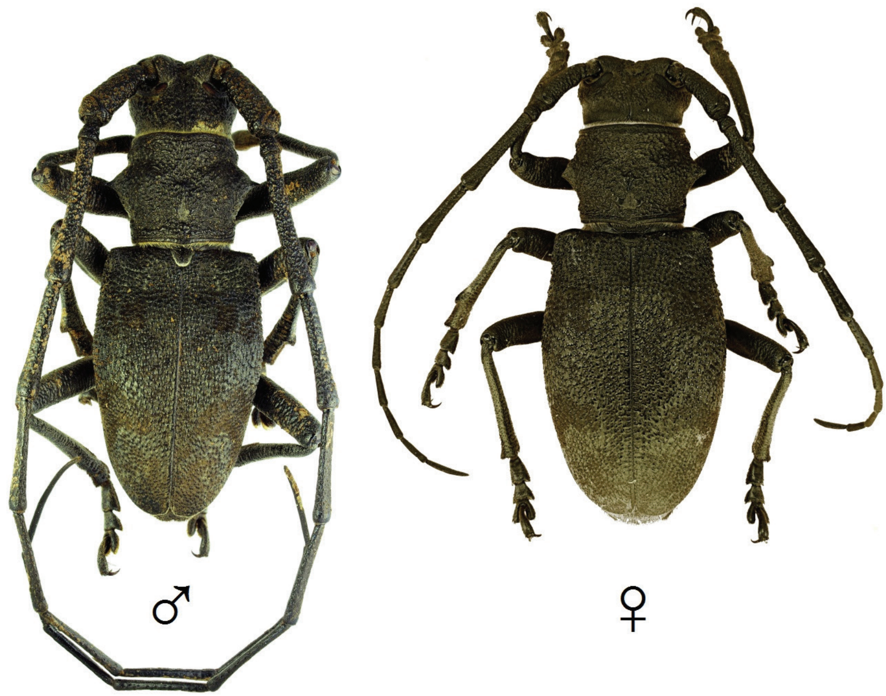

Figure 4. Sexual dimorphism in *Morimus asper asper* (photo by Federico Romiti).

Larval ecology

The larval development takes place in the wood of trunks and stumps and is believed to be completed in three or four years under natural conditions (Stanić 1985, Luce 1996), but may take less time in captivity (Pavan 1948a, Romero-Samper and Bahillo 1993, Dojnov et al. 2012). Generally, authors indicate tree species of several genera and families as larval food sources for *M. asper* (e.g. Sama 2002, Dojnov et al. 2012). However, it is often not clear if the host tree species, cited in the literature, were identified by observing adults or by having observed successful development and emergence of freshly metamorphosed individuals. In fact, observation of an adult on a tree does not prove that the species can reproduce in the wood of this plant species. For example, Romero-Samper and Bahillo (1993) reported, for the Iberian Peninsula, that adults were detected on eight tree species, but larvae were observed only in *Fagus sylvatica*, *Quercus robur*, *Q. faginea*, *Populus nigra* and *Pinus radiata*. Most authors concur that *M. asper* is a polyphagous species (e.g. Luce 1996, Sama 2002, Juillerat and Vögeli, 2004, Polak 2012). According to Sturani (1981), who reported the results obtained by collecting wood attacked by the larvae of longhorn beetles and keeping them alive up to adult emergence, *M. asper* is extremely polyphagous and has emerged from the wood of *Abies*, *Picea*, *Acer*, *Alnus*, *Castanea*, *Platanus*, *Juglans*, *Populus*, *Prunus*, *Quercus*, *Salix*, *Ulmus*, *Tilia* and *Fagus*. Subsequent authors confirmed the extreme polyphagy of this species (e.g. Luce 1996, Sama 2002, Juillerat and Vögeli 2004, Polak 2012) and

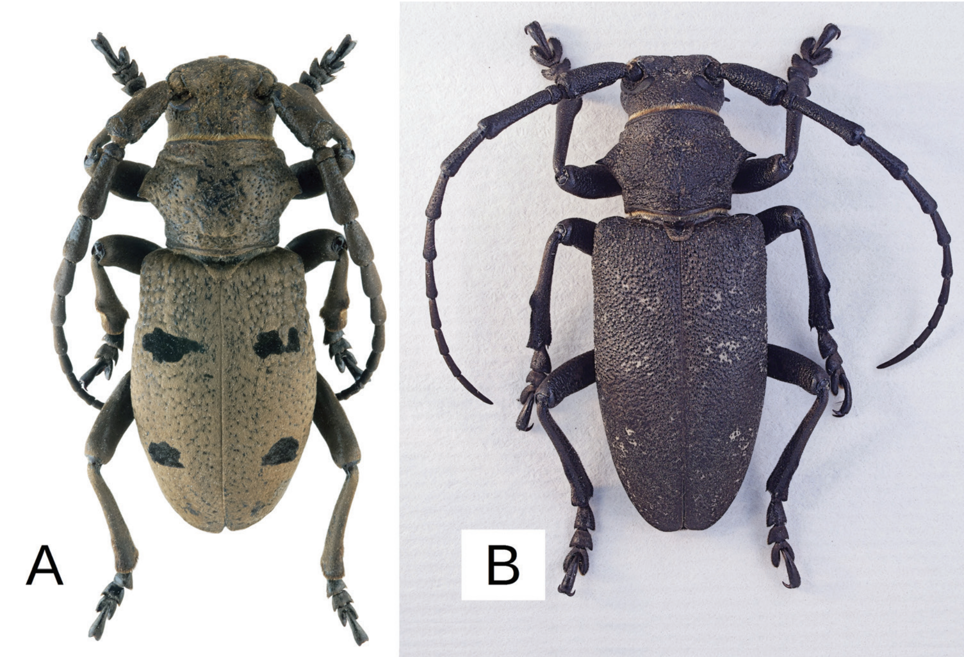

Figure 5. **A** *Herophila tristis* (Photo by Michal Hoskovec) **B** *Lamia textor* (Photo by Federico Romiti).

added new host plants to the lists. For Slovenia, Polak (2012) indicated as host plants *Fagus sylvatica*, *Quercus* spp., *Carpinus betulus*, *Acer* spp., *Castanea sativa*, *Abies alba* and others, while Vrezec et al. (2010) reported that the species selected *Quercus* sp. and *Abies alba*, but less so for *Fagus sylvatica* and *Picea abies*. In Romania, Bărbuceanu et al. (2015) observed adults of *M. asper* on *Quercus* sp., *Fagus sylvatica*, *Robinia pseudacacia* and *Prunus avium*, but they indicated that *Quercus petraea* seems to be the most important tree for larval development. Other Romanian authors more generally reported that this beetle prefers the dead wood of oak and beech trees (Fusu et al. 2015).

In the literature, no information was found on predators of *Morimus* adults.

Adult ecology

Morimus asper lives over a wide altitudinal range and the phenology of local populations is related to altitude. For example, in Slovenia, this species was observed between 150 and 1,240 m a.s.l. but is most common between 300 and 900 m a.s.l. (Vrezec et al. 2009). It was found up to an altitude of 1,500 and 1,800 m a.s.l. in Bulgaria (Bringmann 1996, Anonymous 2015) and between 10 and 1,000 m a.s.l. in the Iberian Peninsula, with single records up to 1,500 m a.s.l. (Romero-Samper and Bahillo 1993). In Italy, the altitudinal distribution of *M. asper* extends from sea level to 1,800 m a.s.l. (Trizzino et al. 2013, Bologna et al. 2016) and this has also been confirmed by a citizen science approach which collected data on this species between 2 m and 1,870 m a.s.l. (Campanaro et al. 2017).

It is generally believed that the adults of *M. asper* are long-living (Stanić et al. 1985, Polak 2012). In fact, overwintering adults are the first to emerge in spring and can also reproduce in the second year (Polak 2012, Rossi de Gasperis et al. 2016). Adults in captivity can live for up to 560 days (Stanić et al. 1985).

The period of the year when adults are active is quite long when compared to other insects but seems to be variable. For a site in Slovenia at 630 m a.s.l., Polak (2012) reported that adults were active from the beginning of May until the end of August, with males starting to appear slightly earlier than females. Drovenik and Pirnat (2003) observed adults from May to July, while Vrezec (2008), analysing data not collected systematically, found that *M. asper* was active from 2 February to 30 September, with most observations being made between 19 May and 11 July. In Romania, adults are active between April and the first half of August, with sporadic observations until late October (Bărbuceanu et al. 2015) and in Bulgaria between April and August (Bringmann 1996). In the Iberian Peninsula, adults are active from the second half of April until early or mid September with the peak of activity being between late July and early August (López-Vaamonde et al. 1993, Romer-Samper and Bahillo 1993). In contrast, Polak (2012) observed two peaks of activity in Slovenia, the first from the end of May to early June and the second between the end of July and early August and suggested that the second peak in August was the result of freshly emerged specimens. Adults enter diapause in August or September (Stanić et al. 1985, Luce 1996). In the plains of northern Italy (Bosco della Fontana, Mantova), *M. asper* was found to be active from late March to mid-July with the peak of activity in April (Hardersen et al. 2017), while in the Julian Alps (about 850 m a.s.l.) adults were observed from mid-May to mid-August (Leonarduzzi 2016). In the context of a citizen science approach carried out in Italy, *M. asper* was recorded from 8 January to 29 October, with large numbers observed from mid-April to mid-August (Campanaro et al. 2017). An important point of this study was the observation that peak activity was observed ever later during the year as altitude increased. Whereas peak activity of *M. asper* was observed at low altitudes (0–400 m) on 23 May, at an altitude of 1,201–1,600 m, the highest activity of *M. asper* resulted on 27 June (Campanaro et al. 2017).

Adults need to feed in order to survive for so many months. However indications on the food consumed in the wild are very scarce. Drovenik and Pirnat (2003) indicate that adults feed on sap from wounded trees and adults in captivity were found to feed on the bark of tree branches (Vrezec et al. 2010, R. Fabbri, pers. com.).

Morimus asper is mainly active in the evening and during the night (e.g. Romero-Samper and Bahillo 1993, Merkl and Hegyessy 2008, Polak 2012). At Bosco della Fontana, *M. asper* was observed with the highest abundance (and with the highest detectability) between 20:00h and 24:00h; however, the species was also detected during the day, but less than 30% of individuals were observed at 12:00h when compared to the peak of abundance (Hardersen et al. 2017). Similarly, Romero-Samper and Bahillo (1993) reported that *M. asper* is generally active during dusk/night but it is also not uncommon to observe adults during the day, even during the hottest hours. In contrast, Stanić et al. (1985) observed that adults are inactive from 12:00h to 15:00h, regardless of the temperature. According to Polak (2012), the activity of adults changes during the season: in spring the peak of activity was observed at midday whereas, during hot summer days with temperatures above 27°C, breeding activity shifted to late afternoon and night-time. Polak (2012) considered 17–27°C as the temperature limits of activity, whereas Stanić et al. (1985) observed active adults in a slightly more extended range of temperatures (12–30°C) and the data provided by Leonarduzzi (2016) showed a reduced activity below 17°C. Under inappropriate weather conditions, adults usually hide amongst loose bark or within holes in the earth (Polak 2012).

Adults of *M. asper* are attracted by damaged trees and recently cut wood (Drovenik and Pirnat 2003, Chiari et al. 2013) and the probability of observing adults increases with the volume of the wood (Chiari et al. 2013). Females oviposit in dead wood with bark still attached, with a preference for large standing trees, trunks on the ground and large stumps (Campanaro et al. 2011). They can also be found on log piles, provided that the bark is still present (Campanaro et al. 2011). According to Bărbuceanu et al. (2015), adults can be found on trunks and stumps, recently cut trees and trunks of old trees. Romero-Samper and Bahillo (1993), however, reported that females choose stumps, trunks of trees that had recently died or trees which are alive but weakened and recently cut trees (maximum two years previously). Polak (2012) noted that the stumps served as meeting points for mating and for breeding and that some fresh stumps were preferred by males. Stumps of trees cut more than one year before are hardly ever visited and old, dry and barkless trees are not attractive (Polak 2012).

Males select stumps that are most attractive for females and here usually stand in a typical "displaying posture" whereas other males, which are unable to defend a territory, permanently wander around (Polak 2012). In contrast, females showed no preference for a particular stump, were frequently observed away from dead wood and mated repeatedly with different males (Polak 2012). Males are observed more frequently than females and also have a higher probability of being recaptured (Chiari et al. 2013, Bărbuceanu et al. 2015), in accordance with the sex-specific behaviour described above.

Life cycle

The female starts oviposition about 16 days after emergence, gnaws with her mandibles into tree bark and lays one egg in each pit created, while the male exhibits mate-guarding to discourage other males (Polak 2012). Females lay eggs in dead wood, preferring large dead trunks, standing or fallen and are less attracted by trunk diameters less than 13 cm (Hardersen et al. 2017). Females are also attracted by piles of wood (Anonymous 2015), also ovipositing in physiologically debilitated trees or stumps which contain developing larvae hatched in the previous year (Dojnov et al. 2012, Polak 2012). Each female can lay more than one hundred eggs during the entire season (Stanić et al. 1985, Dojnov et al. 2012). In the laboratory, overwintering females can lay eggs during a second oviposition cycle after a diapause of at least 4 months. This period of inactivity is likely to be longer in nature, since females do not lay eggs at temperatures lower than 21°C (Stanić et al. 1985). Egg development lasts about 9–12 days and ends with the hatching of the larvae which feed by excavating subcortical galleries (Romero-Samper and Bahillo 1993). Dojnov et al. (2012) observed 5 or 6 larval stages (in some cases up to 12) in the laboratory, with different relative average durations (8, 11, 16, 23, 31 and 23 days). These data refer to larvae obtained from eggs laid by individuals collected in the field. The average rate of larval mortality in the laboratory for the first and the second generation were 9.7% and 20.6% respectively, while mortality for completion of larval development was between 10.3% and 34.9% (Dojnov et al. 2012). At the end of the last larval stage, the larvae create long pupal cells in the wood, up to 8 cm in length (Romero-Samper and Bahillo 1993). The pupa matures in 18 to 23 days (Romero-Samper and Bahillo 1993, Dojnov et al. 2012). The adult remains inside the pupal cell for another 14–20 days prior to emergence, producing a circular exit hole of 8–12 mm in diameter (Romero-Samper and Bahillo 1993). Altogether, the duration of the life cycle of larvae observed in the laboratory varied between 218 and 313 days (Dojnov et al. 2012), while under natural conditions, the development lasts 3–4 years (Stanić et al. 1985). As discussed above, adult *M. asper* are able to overwinter and can survive for more than a year (Stanić et al. 1985, Romero-Samper and Bahillo 1993, Dojnov et al. 2012, Polak 2012, Rossi de Gasperis et al. 2016). The life span of females in the laboratory ranged from 72 to 560 days (Stanić et al. 1985) and in the wild can exceed 400 days (Rossi de Gasperis et al. 2016).

Threats and conservation

Morimus funereus (now considered a subspecies of *M. asper*) is included in Annex II of the Habitats Directive. In the third national report under the Article 17 of the Habitats Directive, the overall assessment of the conservation status for *M. funereus* was "favourable" (Genovesi et al. 2014). This taxon is listed as a species in the IUCN Red List of Italy (Audisio et al. 2014, Carpaneto et al. 2015). It is included in the category Vulnerable (VU) by the IUCN Red List of Italy with the same status being given to the species in 1996 on a global scale (World Conservation Monitoring Centre 1996). Nevertheless, World Conservation Monitoring Centre (1996) and Carpaneto et al. (2015) suggested that *M. funereus* should probably be treated as a subspecies of *M. asper* (*sensu lato*). A revision of its taxonomic status is all the more urgent given the recent results on the existence of a single species throughout Europe which should be named *M. asper* and which is supported by a recent molecular study (Solano et al. 2013). The need to clarify the taxonomic position of the different "forms" of the genus *Morimus* is also highlighted by the fact that the taxon *asper* is not listed in any of the above documents.

One of the main threats to *M. asper*, reported in the literature, is the loss of habitat, such as the removal of branches and logs from the forest floor, as well as of standing dead or dying trees (Cerretti 2008, Dojnov et al. 2012, Trizzino et al. 2013, Rossi de Gasperis et al. 2016). Another threat resulting from forest management is the felling and removal of large trees which are debilitated and which are important larval habitats for *M. asper* and other saproxylic beetles (Audisio et al. 2014, Carpaneto et al. 2015, Rossi de Gasperis et al. 2016). The loss of suitable habitat can lead to a substantial reduction in the abundance of *M. asper* and the continued decline of resources can diminish the number of occupied sites (Dojnov et al. 2012, Rossi de Gasperis et al. 2016). The loss of suitable habitats can also lead to an isolation of the occupied areas, a factor particularly important for *M. asper*, given its low mobility (Cerretti 2008, Trizzino et al. 2013).

A further threat for this longhorn beetle is caused by the forestry practice of leaving freshly cut wood in large piles along forest roads for extended periods and during the breeding season between April and August (Polak 2012). These wood piles can act as “ecological traps” (*sensu* Robertson and Hutto 2006) for *M. asper* and other saproxylic beetles, as they are attracted to the timber where females lay eggs but, usually, this timber is removed and used commercially before the larvae can complete their life cycle. The large wood piles created by commercial forestry operations are particularly attractive for *M. asper* as the probability of occupancy increases with increasing volume of wood (Chiari et al. 2013). This is all the more worrying as the rest of the forest is generally depleted of dead wood, particularly of large diameter trunks. The negative effects can be mitigated by removing the piles before they are colonised (Hedin et al. 2008). It is important to consider that the wood piles proposed for monitoring *M. asper* (see below) are used for oviposition by females of *M. asper* (and other saproxylics). Therefore, it is important to leave this wood in the forest in order to facilitate successful reproduction of the species (Chiari et al. 2013, Hardersen et al. 2017).

Review of monitoring methods in European countries

The methods so far proposed for the monitoring of *M. asper* can be assigned to one of two general strategies: (1) searching/capturing adults which are attracted by freshly cut wood and (2) searching for adults along transects. However, none of the methods proposed has been tested at several sites and/or for several years. In the following paragraphs, an overview of the monitoring methods published for different European countries is presented.

Slovenia

In this country a standard method for the monitoring of *M. asper* has been published by Vrezec et al. (2009). Surveys were carried out with pitfall traps, placed in groups of two or three around fresh stumps (up to one year from the felling of the tree). The traps were fitted with a funnel (Figure 6) to prevent the escape of captured individuals (Vrezec et al. 2009). During these visits, the stumps were also checked for the presence of adults. The combination of pitfall traps and checking stumps significantly increases the probability of detecting the species (Vrezec et al. 2009, 2012). The traps were checked every day after their installation for a total of five days. According to Vrezec (2008), the monitoring should be carried out between the second half of May and the end of June, which is considered the optimal period. Each selected area was monitored using 25 sampling units (a stump with 2 or 3 traps). The problem with this method is that it is based on stumps created by felling trees and therefore cannot be applied in forests where no trees have been cut (Vrezec et al. 2012).

Figure 6. Pitfall traps used by Vrezec et al. (2009).

In addition to the standard monitoring method described above, *M. asper* is recorded in the entire territory of Slovenia by collecting records from the public and this Citizen Science approach is an integral part of the national monitoring scheme. To engage the public, various ways of communication (television, local newspapers, national newspapers, websites, social media etc.) are used, as well as posters which are exhibited in schools, shelters, protected areas etc. (Vernik 2014).

In a further survey applied in Slovenia by Polak (2012), stumps were checked for the presence of adults from the first week of May until the last week of August. For this study, stumps of freshly cut trees were selected (avoiding old and dry ones) in areas where trees had been felled. A total of 14 stumps were selected and each checked 35 times. Polak (2012) found that females were less visible and therefore less detectable than males. The number of observed adults fluctuated daily and these fluctuations were probably influenced by climatic conditions and the time of day in which the surveys had been carried out.

Bulgaria

The monitoring protocol used in Bulgaria (Anonymous 2015) was based on transects of a total length of 1km, carried out by two people walking next to each other. Both observers searched for *M. asper* on either side. Monitoring should be carried out in the afternoon-evening (15:00h-19:00h) and should last one hour. Adults were searched for on trunks of old dead standing trees, large branches on the ground and piles of wood. Records were registered every hour. Best results were obtained when the monitoring was repeated 10 times between May and August.

Romania

In Romania, the monitoring protocol (Fusu et al. 2015) was based on transect walks with a total length of 500 m and a width of 20 m. The minimum time for a transect was 30 minutes and the distance between two transects was 100 m. If possible, five transects were carried out in each area and these were to be conducted by two persons.

Hungary

For Hungary, Merkl and Hegyessy (2008) recommended not to undertake monitoring for *M. asper* as it is difficult methodologically. The method they proposed is based on line transects with a width of 20 m to be carried out in forest areas measuring at least 1ha. Adults were to be searched by following the longest straight line which can be placed in a given area and were counted while walking the transect. Since *M. asper* is mainly active in the evening and at night, it was recommended to also search shaded parts of the logs, stumps and log piles and the underside of freshly cut wood from oaks which had been placed against trunks. The survey was to be carried out four times in consecutive weeks.

Italy

For Italy, the first method proposed for the monitoring of *M. asper* was published by Campanaro et al. (2011) and was based on searching for adults visually and marking them. Standing old dead trees, fallen tree trunks, large branches on the ground, large stumps, wood piles made of large and medium-sized wood and trunks of old and senescent trees were investigated. The surveys were carried out during the day and during the night, but the authors recommended carrying out the fieldwork preferably during the late afternoon (e.g. from 15:00h to 19:00h). Chiari et al. (2013) tested freshly cut log piles as bait for monitoring of *M. asper* in the Nature Reserve Bosco della Fontana. Altogether, they used 29 log piles and counted the number of observed individuals daily between 3 and 8 May 2010. Wood piles with volumes of 0.50 m^3 and 0.25 m^3 were occupied with a cumulative probability of 99% and 95% respectively and the probability of occupancy increased with the volume of wood piles. In summary, the freshly cut log piles were shown to be a good method for monitoring the presence and the abundance of *M. asper*. Chiari et al. (2013) suggested that, in a habitat similar to the ancient forest of Bosco della Fontana, the most efficient allocation of resources for standard monitoring of *M. asper* is by surveying 33 wood piles of at least 0.25 m^3 five times. Trizzino et al. (2013) recommended the use of freshly cut log piles which are built from a variable number of logs (e.g. 15–30), at least 30–60 cm long and with a diameter between 20 cm and 40 cm. These are to be arranged along linear transects, at a distance between 30 m and 50 m. The authors also suggested applying the mark-recapture method. A minimum of six monitoring sessions should be carried out at least every three days. Bologna et al. (2016) also recommended the use of freshly cut log piles for monitoring.

Methods

During this research, the log piles used had a standard volume of 0.3 m^3 and were employed to address a number of objectives, in different years and in different study areas. Research was carried out during the period 2014–2016 and in two forest reserves, Bosco della Fontana in northern Italy (Province of Mantova, Italy, 25 m a.s.l.) and the Parco Naturale Regionale delle Prealpi Giulie in the Julian Alps, north-eastern Italy. At Bosco della Fontana, the study sites were situated between 45.19961°N, 10.73476°E and 45.19848°N, 10.74199°E. In the Prealpi Giulie, the research was conducted in a forest of the municipality of Resia, in the locality Starmiza di Resia (between 46.343490°N, 13.299400°E and 46.341420°N, 13.307800°E). The statistical analyses were performed using the programme R version 3.3.1 (R Development Core Team 2015). Generalised Linear Models (GLMs) for overdispersed count data with a Poisson distribution to test for differences between the different age classes, followed by a post-hoc Wilcoxon pairwise test were used. The following methods were tested: pitfall traps baited with potentially attractive compounds, stumps, trunks and freshly cut log piles. The log piles were used to provide answers to the following questions: (1) Do season and time of the day influence the detection probability and/or abundance of the species; (2) Does the diameter affect the number of *M. asper* observed on the piles; (3) Is the number of adults observed affected by the age of wood piles and (4) Does the attractiveness of different tree species vary?

Bosco della Fontana 2014

In 2014, freshly cut log piles and pitfall traps baited with chemical compounds were used to address the following questions: (1) do season and time of the day influence the detection probability and/or abundance of the species? (2) do the site covariates affect the detection and/or the abundance? (3) do selected chemical substances attract the species? This research, which employed wood from *Quercus robur* and *Carpinus betulus* of three diameter classes, has already been published (Hardersen et al. 2017). Additionally, an experiment was carried out to investigate whether selected chemical substances attracted *M. asper*. The substances tested were Fuscumol, Fuscumol acetate, Ethanol and Isopropanol (Hardersen et al. 2017).

Bosco della Fontana 2015

In 2015, two experiments were carried to investigate the effect of the age of wood piles on the number of adults observed. The first experiment involved woodpiles built from trees of *C. betulus* which had been cut during the following periods: 19.02.-03.03.2014 (hereafter 03_14), 16–17.12.2014 (hereafter 12_14) and 16–23.03.2015 (hereafter 03_15). These piles were built from wood cut from trunks and branches with a diameter 13–50 cm. For each age-group, a total of 10 wood piles were built in random order at the sides of forest roads, spaced at intervals of 50 m. The adults were searched for once a week from 1 April to 27 May 2015 (i.e. a total of nine surveys) starting at 20:00h. The second experiment, which was carried out once the first had been completed, involved the same wood piles built from trees of *C. betulus* as above. However, the oldest piles (03_14) had been replaced by new ones, built on 27.05–03.06.2015 (hereafter 05_15) from wood with a diameter 13–50 cm. The aim of this second experiment was to test whether the wood piles built in December and March had already lost their attraction by June/July. The adults were searched for once a week from 10 June to 8 July 2015 (i.e. a total of five surveys). Again fieldwork was started at 20:00h. For both experiments the effect of the age of the wood piles on the number of observed *M. asper* was analysed employing the sums of all *M. asper* observed during the surveys.

Bosco della Fontana 2016

In 2016, an investigation was initiated to determine whether the attractive properties of different tree species for *M. asper* varied. At Bosco della Fontana, 28 woodpiles were built from four tree species: *C. betulus*, *Fraxinus ornus*, *Juglans nigra*, *Quercus rubra* which had been cut from 26.01 to 21.03.2016. These wood piles were built from wood cut from trunks and branches with a diameter 13–45 cm and were randomly distributed at the sides of forest roads, spaced at intervals of 50 m. The adults were searched for once a week from 29.03 to 17.05.2016 (i.e. a total of eight surveys) starting at 20:00h. This research has already been published (Leonarduzzi et al. 2017).

Parco Naturale Regionale delle Prealpi Giulie 2015

In the literature, the following structures are cited as attractive for *M. asper*: log piles (Campanaro et al. 2011, Chiari et al. 2013, Anonymous 2015), fallen trunks (Romero-Samper and Bahillo 1993, Polak 2012, Bărbuceanu et al. 2015) and stumps (Romero-Samper and Bahillo 1993, Dojnov et al. 2012, Polak 2012, Bărbuceanu et al. 2015). In order to test which of these structures is more attractive, on 11.05.2015 wood from freshly cut beech (*Fagus sylvatica*) was exposed in the locality Sella Starmiza in the Parco Naturale Regionale delle Prealpi Giulie (Udine province) in 6 sites (coordinates: 46.34344°N, 13.30040°E to 46.34063°N, 13.30829°E) at an altitude between 760 to 870 m a.s.l. Each station was built from two beech trees, which consisted of two trunks (cut to a standard volume of 0.3 m^3), two wood piles (standard volume of 0.3 m^3) and the two stumps created by the felling of the trees. In each station, one wood pile had been built from the lower part of the trunk and one from the upper part. The sites were checked for the presence of adults of *M. asper* according to the following timetable: 29.06.2015 (08:15h-13:10h and 18:20h-21:50h); 30.06.2015 (08:09h-12:10h and 18:07h-21:50h); 01.07.2015 (08:03h-11:18h and 18:15h-20:15h); 28.07.2015 (08:00h-10:57h and 18:00h-20:18h); 30.07.2015 (08:39h-11:12h and 17:37h-20:21h) and 31.07.2015 (08:50h-11:24h and 18:18h-20:56h).

Parco Naturale Regionale delle Prealpi Giulie 2016

In 2016, an investigation was initiated to determine whether the attractive properties of different tree species for *M. asper* varied. In the locality Starmiza, the experiment was initiated on 03.05.2016. As it was known that *M. asper* was not evenly distributed (unpublished data), a randomised block design was employed with a distance of 85–215 m between the various blocks. Each block consisted of three piles built from wood of *F. sylvatica*, *Fraxinus excelsior* and *Picea abies*, with diameters of 13–30 cm. Adults of *M. asper* were searched for approximately once a week from 17.05 to 12.08.2016 (i.e. a total of 13 surveys) starting at 18:00h. This research is currently being published (Leonarduzzi et al. 2017).

Results

Bosco della Fontana 2014

Morimus asper was observed with the highest detectability and abundance between 20:00h and 24:00h (Hardersen et al. 2017). Although adults were also detected during the day, at 12:00h the abundance was less than 30% when compared to the maximum values. Additionally, the number of *M. asper* observed was strongly influenced by the characteristics of the wood piles, with wood from *Q. robur* clearly preferred to *C. betulus* and small diameter wood (<12 cm) being least attractive. Hardersen et al. (2017) recommended building piles from wood with a diameter >13 cm. An experiment, which investigated whether selected chemical substances attracted *M. asper*, showed that Fuscumol, Fuscumol acetate, Ethanol and Isopropanol did not attract *M. asper* into pitfall traps (Hardersen et al. 2017).

Bosco della Fontana 2015

The investigation of the effect of the age of wood piles on the number of observed *M. asper* revealed that the age of the timber was an important factor to consider. In the first experiment, the number of individuals observed on the piles built from wood which had been cut more than a year ago (03_14) was approximately 1% of that observed on piles built during winter (Figure 7A), a highly significant difference (Wilcoxon signed rank test, 03_14 vs. 12_14: p=0.006; 03_14 vs. 03_15: p=0.012). Interestingly, the numbers of individuals observed on the wood piles built in December (12_14) and in

March (03_15) were very similar, with a non-significant difference (Wilcoxon signed rank test, 03_15 vs. 12_14: p=0.49).

For the second experiment, the GLM was significant (z=2.188, p=0.0287) and, on the wood piles built during the winter (12_14 and 03_15), less than 20% of *M. asper* were observed when compared with the new wood piles built between 27.5 – 3.6.2015 (Figure 7B). This difference was significant (Wilcoxon signed rank test, 03_15 vs. 05_15: p=0.017; 12_14 vs. 05_15: p=0.017). Thus, during the summer months, the wood piles became less attractive after two months, presumably because the wood was drying out. In contrast, no difference was found between the log piles built in December and March (Wilcoxon signed rank test, 12_14 vs. 03_15: p=1.0), as in the previous experiment. Both experiments showed that the age of the wood was important for the number of *M. asper* observed. Only fresh wood was highly attractive and the wood piles became less attractive much more quickly during summer than in winter.

Bosco della Fontana 2016

This experiment clearly showed that adults were observed more frequently on the wood of some tree species: most individuals were observed on *Juglans nigra* and the least attractive tree species was *Fraxinus ornus* (Figure 8A), with *Quercus rubra* and *Carpinus betulus* being intermediary (Leonarduzzi et al. 2017).

Parco Naturale Regionale delle Prealpi Giulie 2015

Log piles, trunks and stumps attracted *M. asper*, but log piles and trunks permitted the observation of a significantly higher number of individuals, when compared with stumps (Figure 9A). The GLM model was highly significant (z=9.570, p<0.001).

The number of adults observed on trunks and log piles was high and significantly different from that observed on stumps (log piles vs. stumps: p=0.028; trunks vs. stumps: p=0.027). The number of individuals observed on wood piles was lower when compared with trunks, but this difference was not significant (log piles vs. trunks: p=0.481). The phenological data from this experiment showed that the adults of *M. asper* were observed in high numbers exclusively in June and early July (Figure 9B).

Parco Naturale Regionale delle Prealpi Giulie 2016

Similar to the experiment carried out in Bosco della Fontana 2016, this experiment, carried out in the Parco Naturale Regionale delle Prealpi Giulie 2016, showed clear differences in the numbers of individuals observed on the various tree species. *Fagus sylvatica* was the most attractive wood, followed by *Fraxinus excelsior* and *Picea abies* (Figure 8B) (Leonarduzzi et al. 2017).

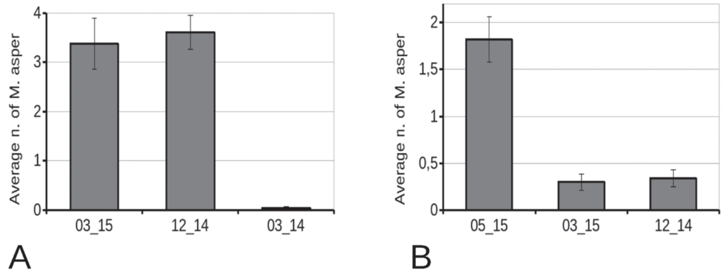

Figure 7. Average number of *M. asper* observed each week on single wood piles built with logs cut in different periods at Bosco della Fontana. **A** first experiment **B** second experiment (for details see text). Error bars represent standard errors.

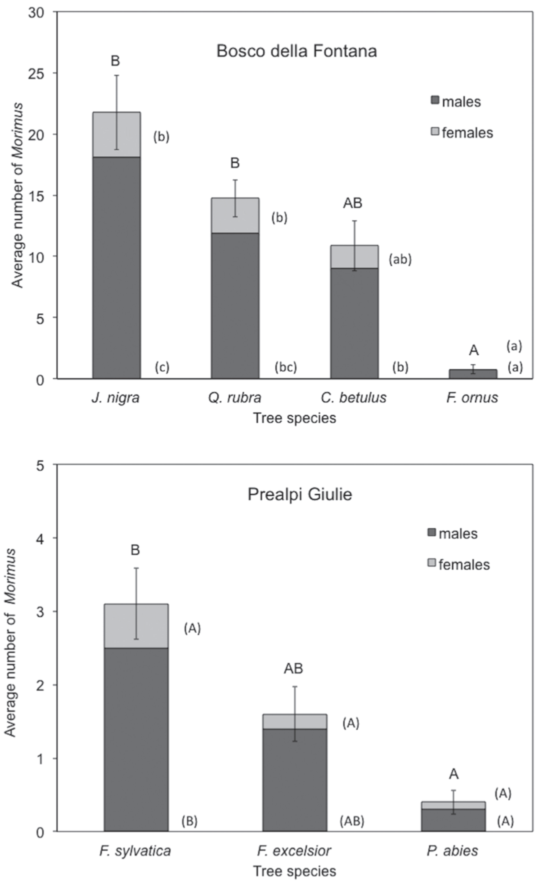

Figure 8. Average number (±SE) of adults of *M. asper* observed per day on single wood piles built from wood of different tree species. Different capital and small letters above columns (total adults) and on the right (males and females) indicate significant differences amongst wood types at the 0.01 and 0.05 levels respectively (Dunn's Multiple Comparisons Test) (see text for details). Figures from Leonarduzzi et al. (2017).

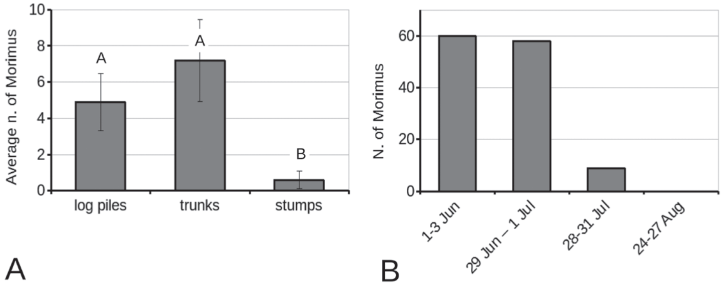

Figure 9. A Average numbers of *M. asper* observed on different structures in 2015 at Prealpi Giulie. Error bars represent standard errors **B** Total number of *M. asper* observed during different periods in 2015 at Prealpi Giulie.

Discussion

Description of the proposed monitoring method

As a standard method for the monitoring of *M. asper*, the use of freshly cut wood piles (Figure 10) is proposed, these attract adults of this species. The freshly cut wood piles, whose attraction was indistinguishable from that of a single log of the same volume, were suitable for detecting the presence of the species and for indicating the population size (Campanaro et al. 2011, Chiari et al. 2013). An important practical consideration, which favoured the choice of wood piles, is that a number of small logs can be transported with relative ease, whereas moving a single large tree trunk requires specialised equipment. Thus, using wood piles is much more versatile.

The wood piles can be made from trees (trunks or branches) which have recently fallen or from freshly cut trees. It is important that the tree had been alive at the beginning of winter and that monitoring starts as soon as the adults become active in spring, as the attraction of the timber will decrease after 1–2 months in summer. Log piles cut to a length of 60 cm lose their attraction faster than trunks and therefore it is recommended cutting the wood for the piles in the two-three weeks preceding the monitoring. The wood piles should be built from a single tree species in order to facilitate interpretations of the results and homogeneity of methods for future monitoring. The choice of the wood to be cut should be guided by the following considerations:

1. choose the dominant native hardwood timber present in the study area (if present, beech, oaks or European hornbeam);
2. choose a locally widespread tree species which will also be available in the future in order to avoid logistical problems during future years in which monitoring is envisaged;
3. consider whether the tree species will be available for cutting in the future (e.g. in nature reserves);
4. choose a tree species known to be attractive. So far, it seems that *F. ornus* and *P. abies* are not attractive for *M. asper*.

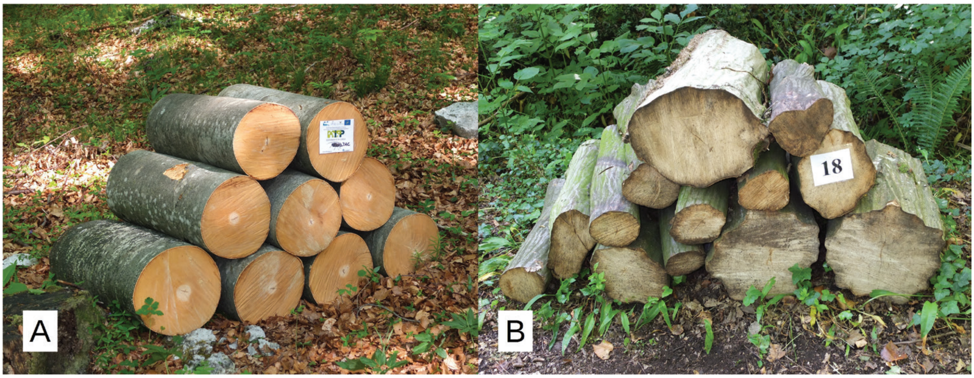

Figure 10. Two wood piles built from freshly cut wood. **A** *F. sylvatica*, freshly built **B** *C. betulus*, two months after being built.

The standard monitoring protocol (Table 1) needs to be repeated at the same site in future years, without any changes to the methodology, to ensure that the data gathered provide reliable information on local populations and can be compared chronologically as well as with other areas investigated.

In an attempt to optimise the use of resources and workforce, it is recommended that log piles be built with a volume of 0.3 m^3, which is the volume of the piles employed during the study and in accordance with the volume indicated by Chiari et al. (2013). It is suggested to cut trees and build the wood piles directly on the site. The excess timber (trunk and logs), which cannot be used to build other wood piles, must be removed from the area investigated as this material constitutes additional wood attractive to *M. asper* and could influence the number of individuals present on the piles built for monitoring. If it is not possible to use trees on site, it is recommended finding nearby sources in order to reduce transport time, to guarantee local eco-types and to facilitate access to the same wood for future monitoring.

The locations of the single wood piles should be chosen to facilitate building and also to make them easy to check during late afternoon/evening. It is therefore recommended to build the log piles along forest roads (with very little traffic) which cross suitable habitat and to avoid steep terrain on either side. It is important to regard the peculiarities of each study area and also to consider the morphology of the terrain, the type of habitats to be monitored and also practical considerations (e.g. distance to be travelled by personnel). In sloping areas, the trees can be cut higher up and the wood piles built further down, at least 50 m from the stumps, taking advantage of the slope when moving cut logs downhill.

In each area, seven wood piles have to be built for monitoring, arranged along linear transects with a distance of 100 m between them. The wood piles are to be checked once a week for five weeks, beginning at the time when *M. asper* starts to be active (April – May). It is recommended to check the wood piles after 20:00h, but if practical problems render this time of the day unfeasible, it is suggested to carry out the field work as late as possible. It is also important to maintain the same time of the day for

Table 1. Summary of the monitoring protocol.

Monitoring protocol	
Method	Freshly cut log piles
Number of log piles	7 for each site to be monitored
Placement of log piles	Along transects
Distance between log piles	100 m
Monitoring period	April-July
Number surveys	5
Frequency of repeats	Once a week
Time of the day	20:00h-24:00h
Number of operators	2
Hours per person	15 hours/person
Equipment	A clipboard, a field sheet, a head torch, a pencil, a clock, holding box for beetles and kneepads

future monitoring activities. The duration of each session (checking seven wood piles) depends on the number of observed individuals and on the distribution of the wood piles in the study area; indicatively, 45 minutes should be allowed for this activity. It is recommended to change the checking order of the wood piles for each session to avoid bias due to controlling the same wood pile always at the same time of the day. In this way, the variabilty of the results for the various wood piles can be reduced.

As stated above, the wood piles are to be checked once a week for five weeks. By controlling the piles once a week, operators are able to shift the day for controlling to avoid days with unsuitable weather conditions. The time-span of five weeks is long enough to guarantee that peak activity will fall in the monitoring period, even if unusual climatic conditions lead to shifts in the phenology of *M. asper*. However, if the local phenology of *M. asper* is not well known (or cannot be reasonably inferred from available data), exclusively for the first year of monitoring, it is recommended to extend the sampling period (e.g. to seven sessions) to better define the period of maximum activity in the study area. The five weeks identified as the period of maximum activity during the first year will be used for future monitoring in order to ensure that the data are comparable. It should also be considered that maximum activity occurs ever later in the year as altitude increases (Campanaro et al. 2017).

The standard method described here, which is based exclusively on visual counts, is the basic survey method. If additional aspects of the local population are to be investigated (e.g. population size, dispersion of individuals, life expectancy etc.), monitoring of the wood piles can be extended using the capture-mark technique. During the Project MIPP, this technique was successfully applied using tags for queen bees glued to the elytra of the adults by Loctite Super Attack Power Flex Gel.

Each year in which monitoring is to be carried out, new wood piles need to be built, as the attraction of the timber declines after a few months (in summer) and, after one year, the wood piles do not attract the species any more. Once the monitoring has been completed in a given year, the wood used for building the piles must be distributed in the forest to ensure the survival of the larvae of *M. asper* and of other saproxylic species.

Protocol, equipment and materials

Building the wood piles (Table 2)

Each log which is used for building a log pile, must be from the same tree species and the trees need to be alive when cut. If a recently fallen tree is used, it is important that it had been alive at the beginning of winter (e.g. trees uprooted by heavy snow). It is recommended to choose trees that allow building more than one wood pile in order to minimise the number of trees to be cut.

It is recommended to cut the wood for the log piles in the weeks preceding the monitoring activities, corresponding to the beginning of the activity by adults of *M. asper*. Altitude and latitude are probably the factors determining the beginning of the period of activity of the adults and this normally falls in the months of April or May. For example, in a mountain area of the Julian Alps of Italy (about 850 m a.s.l.), the species is active from mid-May until early August (Leonarduzzi 2016) and it is therefore recommended to instal the wood piles in early May. In contrast, in Bosco della Fontana (25 m a.s.l.), located in the lowlands of the Po Valley, the species is already active by the end of March/early April and therefore wood piles need to be built during early March (Hardersen et al. 2017). The exact shift in phenology for *M. asper* with increasing altitude is not well known, but Campanaro et al. (2017) found that peak activity of four insect species (also considering *M. asper*) was delayed by an average of 10 days at altitudes higher than 400 m.

The individual logs are to be cut from trunks/branches with a diameter of between 13–45 cm and to a standard length of 60 cm (Figure 10). Each log pile should contain at least one log with a diameter larger than 30 cm. It is recommended to carry out the measurements of the individual logs directly in the field during the installation of the log pile, using a ruler or a tree calliper. Logs must be positioned in 2–4 layers. Care should be taken to build a stable structure. Once completed, the log pile should cover an area of approximately 60 × 70–100 cm^2 (Figure 10). If the study area is on a slope, one side of the wood pile can be placed against a tree-trunk or against a rock, to prevent the logs rolling downhill.

The volume of each wood pile should be 0.30 m^3 and the desired volume can be most easily and accurately achieved by calculating the volumes of the single logs used for construction. It is therefore recommended to use a spreadsheet (Supplem. material 1: Excel sheet, Volume of log piles) to calculate the volumes of the single logs by entering the diameter (and length if a single trunk were not cut to 60 cm). Once the construction of a wood pile has been completed, it must be identifiable by a unique numerical code and its geographical position needs to be registered with a GPS. The geographical coordinates can also be important for locating the single wood piles for monitoring.

Checking the wood piles

The wood piles are to be checked once a week, during the period of maximum activity of *M. asper* when weather conditions are favourable i.e. without rain and a mean daily temperature between 15 and 26°C (Rossi de Gasperis et al. 2016). The adult activity will entirely stop at temperatures below 12°C (Stanic et al. 1985). If weather conditions are not favourable on a pre-selected day, it is advisable to carry out the fieldwork

Table 2. Building the wood piles (for details see the text).

Building the log piles	
When to build	March-May
Tree species tested: use	*Fagus sylvatica*, *Quercus* spp., *Carpinus betulus*, *Juglans nigra*
Tree species tested: avoid	*Fraxinus ornus*, *Picea abies*
Volume of wood	0.30 m^3
Diameter of trunks/branches	13–45 cm
Length of logs	60 cm
Work days	1–2 days
Number of operators	3, at least one forest worker (felling, chainsaw work)
Materials	Ruler or a tree calliper, GPS, numerical code

on another day, as soon as possible. The interval between successive monitoring sessions should be 5–9 days.

The protocol requires the presence of two operators who simultaneously search for *M. asper* by sight on the surface of the wood pile, amongst the logs and at the base of the pile. It is important to use a torch (e.g. head lamp) to carefully check the spaces between the logs as adults tend to hide, often in a resting position, in these relatively inaccessible places. The use of kneepads is recommended. Once an adult has been found, it is temporarily placed in a plastic container with a lid to prevent escape. After having thoroughly checked one side of the wood pile, the operators switch sides and thus each operator checks the entire wood pile. Once the search of the wood pile has been completed, the number of individuals collected is counted, specifying the number of males and females. After the compilation of the field sheet (see Supplem. material 2: Field sheet) the individuals must be released on to the same log pile. The required equipment includes: a clipboard, field sheet, head torch, pencil, clock, holding box for beetles and kneepads.

Constraints, spatial validity and possible interferences

The mark-recapture studies carried out by Rossi de Gasperis et al. (2016) and the research carried out during this project (unpublished data) showed that the large majority of adult *M. asper* moved less than 200 m during the adult stage. Therefore, at present, it can be reasonably assumed that the validity of the results of the monitoring extends to an area surrounding the wood piles up to a maximum of 200 m. In other words, the monitoring method proposed here provides valid data for an area of about 36.5 ha. If the area monitored is located within a homogeneous forest (e.g. tree composition, age of trees, management, dead wood etc.), the validity extends to this area.

A possible interference in the areas to be monitored is represented by freshly felled trees, as these might affect the number of *M. asper* observed. If logging has been carried out just prior to the period of monitoring (or during the monitoring) close to the selected forest area, it is likely that the logs created by the felling operation may have attracted the adults away from the monitoring stations, thus rendering the data invalid. Stumps and trunks older than two years are unlikely to attract *M. asper*. A further aspect to be considered is the fact that people might remove logs from the wood piles built for monitoring. This is more likely along roads that are accessible by car and in forests where the collection of timber for firewood is permitted or not prevented because of poor surveillance. The best strategy for avoiding the removal of logs is to place the log piles in areas which are under surveillance or where access is limited. A further problem might be the unauthorised collection of individuals by amateur entomologists, given that wood piles attract adults of *M. asper*. For these reasons, it is recommended to attach plates which explain the monitoring and the importance of the log piles. The surveillance and the plates, described above, are means to reduce these risks. A final aspect to be considered is the interaction with other monitoring activities. Methods employed for the monitoring of *Rosalia alpina* (Linnaeus, 1758) might also be attractive for *M. asper*. It is recommended to allow a distance of a least 1,000 m between monitoring stations for the different species.

Counting, quantification and data sharing

In order to assess the conservation status of populations of *M. asper* for a given season and for a given area, a reference value is calculated as follows:

1. For each session, calculate the total number of individuals (males + females) by adding up the number of individuals found in each wood pile;
2. Calculate the mean value of the total number of individuals counted in each session, excluding the session with the lowest number. Removing the lowest count, as proposed for other insect species (Trizzino et al. 2013), allows the elimination of eventual outlier values due to adverse climatic conditions (e.g. low temperature and/or rainfall) or other factors which do not represent the local population and is meant to reduce the variability of the final value.

Table 3 reports an example of calculation of the mean value of the individuals counted. The mean value obtained is the reference value for the assessment of the conservation status of the species in a given year for a single monitoring station (i.e. 7 log piles). This value allows the comparison of long-term data and the identification of the population trend. However, the statistical analysis of trends in monitoring data is complex (e.g. Schmidt and Meyer 2008, Schmucki et al. 2016). The range of values

Table 3. Example of the calculation of the reference value for the monitoring of *M. asper* in one site. Sessions represent single evenings when the wood piles were checked. The numbers given in the columns Lp. 1 – Lp. 7 represent the total number of *M. asper* observed on one log pile. (Lp. = Log pile).

	Lp. 1	Lp. 2	Lp. 3	Lp. 4	Lp. 5	Lp. 6	Lp. 7	Total
Session 1	1	2	4	3	2	3	1	16
Session 2	3	6	5	5	6	3	3	31
Session 3	3	5	7	7	7	4	5	38
Session 4	2	4	3	2	2	0	0	13
Session 5	4	7	8	5	3	5	4	36
Average value for the four counts with the highest average total								30.25

obtained during the MIPP project varied between 2.5 (Parco Naturale Regionale delle Prealpi Giulie, in 2016) and 32.75 (Bosco della Fontana, in 2015).

Acknowledgements

We would like to thank our colleagues, students and friends who helped during the surveys: C. Baldi, A. Campanaro, S. Corezzola, A. Cuccurullo, S. Garcia, T. Gerritsen, P. Giangregorio, E. Minari, L. Redolfi De Zan, R. Rollins, L. Spada, I. Toni, A. Zauli. We are also indebted to M. Ascari and O. Conti who helped in building the log piles at Bosco della Fontana. Special thanks to Pierpaolo Rapuzzi (Cialla di Prepotto, UD) for taxonomic information and advice. We are grateful to all the staff of the Parco Naturale Regionale delle Prealpi Giulie, in particular: Stefano Santi, Giulio Goi, Marco Micelli and Marco Di Lenardo. We would like to thank Kajetan Kravos, Michal Hoskovec and Federico Romiti for allowing us to use their photos and two reviewers for their constructive comments, which helped to improve the manuscript. The present work was developed within the EU project LIFE11 NAT/IT/000252, with the contribution of the LIFE financial instrument of the European Union.

A special permit was obtained from the Italian Ministry of Environment for handling and capturing individuals of the target species (collection permit: Ministero dell'Ambiente e della Tutela del Territorio e del Mare – DG Protezione della Natura e del Mare, U. prot PNM 2012-0010890 del 28/05/2012).

LIFE 11 NAT/IT/000252

With the contribution of the LIFE financial instrument of the European Union.

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Supplementary material 1

Excel sheet, Volume of log piles

Authors: Sönke Hardersen, Marco Bardiani, Stefano Chiari, Michela Maura, Emanuela Maurizi, Pio Federico Roversi, Franco Mason, Marco Alberto Bologna

Data type: specimens data

Link: https://doi.org/10.3897/natureconservation.20.12676.suppl1

Supplementary material 2

Field-sheet *Morimus asper*

Authors: Sönke Hardersen, Marco Bardiani, Stefano Chiari, Michela Maura, Emanuela Maurizi, Pio Federico Roversi, Franco Mason, Marco Alberto Bologna

Data type: Field-sheet

Link: https://doi.org/10.3897/natureconservation.20.12676.suppl2