

Review article**An overview on the most outstanding Italian endemic moth, *Brahmaea (Acanthobrahmaea) europaea* (Lepidoptera: Brahmaeidae)**

Fabio MOSCONI^{1,2,*}, Alberto ZILLI³, Renato SPICCIARELLI⁴, Emanuela MAURIZI^{1,5}, Augusto VIGNA TAGLIANTI⁶, Paolo AUDISIO^{2,6}

¹ Council for Agricultural Research and Economics, Research Centre for Agrobiology and Pedology (C.R.A.-A.B.P) - Via Lanciola 12/A, I-50125 Cascine del Riccio (Florence), Italy - fabio.mosconi@gmail.com

² Department of Biology and Biotechnologies "Charles Darwin", Sapienza University of Rome - Via Alfonso Borelli 50, I-00161 Rome, Italy - paolo.audisio@uniroma1.it

³ The Natural History Museum, Life Sciences, Insect Division - DC2-2N, Cromwell Road, London SW7 5BD, UK - a.zilli@nhm.ac.uk

⁴ School of Agricultural, Forest, Food and Environmental Sciences (SAFE), University of Basilicata - Viale dell'Ateneo Lucano 10, I-85100 Potenza, Italy - renato.spicciarelli@unibas.it

⁵ Department of Sciences, Roma Tre University - Viale Guglielmo Marconi 446, I-00146 Rome, Italy - emanuela.maurizi@uniroma3.it

⁶ Museum Centre, Zoological Museum, Department of Biology and Biotechnologies "Charles Darwin", Sapienza University of Rome - Piazzale Valerio Massimo 6, I-00162 Rome, Italy - augusto.vignataglianti@uniroma1.it

* Corresponding author

Abstract

The state of knowledge about the European Bramea, *Brahmaea (Acanthobrahmaea) europaea* Hartig, 1963, is briefly summarized in relation to growing concern about the conservation status of the most outstanding Italian endemic moth species.

Key words: *Brahmaea (Acanthobrahmaea) europaea*, Brahmaeidae, Lepidoptera, endemic species, host-plants, conservation, Italy.

Introduction

Brahmaea (Acanthobrahmaea) europaea Hartig, 1963 (Fig. 1), the so called European Owl Moth or European Bramea, was discovered by Federico Hartig (Fig. 9) in 1963 in Basilicata, Southern Italy (Hartig 1963, 1966, 1997; Sbordoni & Forestiero 1984; Stella 1987; Vigna Taglianti & Zilli 2008).

Subsequent research has shown that *B. europaea* is an Italian endemic with exceedingly restricted range (e.g. Rougeot 1971, 1975); in fact, the species occurs only in a very small area, mainly around Mount Vulture, and in a few localities along the valleys of the rivers Basento and Cavone (provinces of Potenza and Matera; Fig. 8).

Brahmaea europaea was long considered as the only Brahmaeid present in Europe, a family which in its strict sense included a few species from Asia and the Afrotropical region (Minet 1994; Lemaire & Minet 1999; Nässig & Naumann 2010). Nonetheless, following outcomes of molecular studies, the family Lemoniidae, with five species in Europe (all in the genus *Lemonia* Hübner, 1820), two of which also in Italy, was recently merged with the Brahmaeidae (Regier et al. 2008; Zwick 2008; Zwick et al. 2011).

Taxonomy and Systematics

Brahmaea (Acanthobrahmaea) europaea Hartig, 1963 is the only species of *Brahmaea* Walker, 1855 occurring in Europe (Karsholt & van Nieuwerkerken 2004); most species diversity by this genus is concentrated in the Far East (e.g. Chu & Wang 1977; Zhang & Yang 1993, 1994; Minet 1994; Nässig & Paukstadt 1990; Nässig & Treadaway 1998; Paukstadt et al. 2000; Hao et al. 2002; Naumann & Brosch 2005).

From a systematic point of view the taxa more closely related to *B. europaea* are the so-called "palaeartic brameas", that is members of the *Brahmaea ledereri* Rogenhofer, 1873-*Brahmaea certhia* (Fabricius, 1793) group [*Brahmaea* sensu stricto, after the meaning of Nässig & Nye (1991, and ICZN 1992)], some of which from time to time associated with the (sub)generic name *Brachygnatha* Zhang & Yang, 1993.

The only other *Brahmaea* species known to occur in the Western Palaearctic is *B. ledereri* from the Taurus Mts across SE Anatolia to N Iran [= *B. christophi* (Staudinger, 1885); see Nässig 1980; Freina 1982, 1985; Lehmann & Zahiri 2011].



Fig. 1 – Adult of *Brahmaea (Acanthobrahmaea) europaea* (Grotticelle Nature Reserve; photo by V. Viglioglia).

Main diagnostic characters of *Acanthobrahmaea* Sauter, 1967 involve peculiarities of wing veins and the pupa (Sauter 1967, 1986; Rougeot 1971), as this bears rows of stout spines on dorsum of abdominal segments A5-A7 (Fig. 7), and no other related species are known to possess such structures (see e.g. De Freina 1985 for the unarmed pupa of the allied *B. ledereri*).

The haploid chromosome number of the species was assessed by Marini & Trentini (1985) as $n = 32$, a figure close to the modal number ($n = 31$) shown by most members of the related family Saturniidae (Narang & Gupta 1982). No studies were actually dedicated to detailing the phylogenetic relationships of *B. europaea* with putative allies nor to track its biogeographic origin, though it is generally assumed that it represents a relic of tertiary origin (Schepdael 1967; Rougeot 1971; Zilli 1998; Giusti 2014).

Life history and ecology

The moth lives in mixed broadleaved forests dominated by deciduous oaks, ashes and hornbeams with rich under-

growth of privet, hawthorns and *Phyllirea*, at an altitude between 200 m and 800 m (Fig. 3). Adults (Fig. 1) are on the wing only for a short period of the year, during three or four weeks between late March and early May, with a peak of activity in the first half of April (Laplanche 1973; Spicciarelli & Fimiani 2004). After the rapid development and hatching of eggs, about 12–15 days after deposition (Spicciarelli 2013), caterpillars grow fast; fifth instar larvae (Fig. 5) pupate into the ground, where they will remain until the following spring (Fig. 6). The spines present on the abdominal segments (Fig. 7) are likely to support active movements by the chrysalis into the ground, as evidenced by conspicuous daily movements by the pupae in breeding cages observed by Enrico Stella (personal communication, 1986).

The ecological requirements of the species are still poorly known. Adults are active during the early hours of the night, just after sunset, and they are capable of flying also at very low temperatures, even when snowing (Dufay 1970; Spicciarelli & Fimiani 2004).

For a long time, host plants and feeding habits by the larvae remained unknown; in fact, larvae were rarely ob-



Figs 2-7 – 2, Information board at main entrance of Grotticelle Nature Reserve (Basilicata); **3**, edge of a forest habitat, Grotticelle Nature Reserve; **4**, larva of *Brahmaea* (*Acanthobrahmaea*) *europaea* Hartig, 1963 feeding on *Fraxinus angustifolia* subsp. *oxycarpa* (Willd.); **5**, mature larva of *B. europaea* about to pupate (top), and pupa soon after formation (bottom); **6**, hardened and darkened pupa of *B. europaea* a few hours after formation (ventral view); **7**, detail of pupal cremaster of *B. europaea* and three rows of stout spines on segments A5-A7 (dorsal view). Photos 2 and 4-7 by R. Spicciarelli; photo 3 by A. Rositi.

served in nature, though there were rumors that Hartig had occasionally spotted clusters of caterpillars on bushes of narrow-leaved ash [*Fraxinus angustifolia* subsp. *oxycarpa* (Willd.); Oleaceae]. More recently Spicciarelli (1997, 2013, 2014) demonstrated that larvae in the wild actually feed on *Fraxinus angustifolia* subsp. *oxycarpa* (Fig. 4) but also on the evergreen *Phyllirea latifolia* L. (Oleaceae); in captivity larvae would also freely accept *Ligustrum vulgare* L. (Bilek 1965, 1967), whereas they appear to refuse *Fraxinus ornus* L. (Spicciarelli 2014).

All host plants of *Brahmaea (Acanthobrahmaea) europaea* are thus members of the Oleaceae, as for all known palaeartic *Brahmaea* species (Nässig 1980; De Freina 1982, 1985; Konno et al. 2001). Interestingly, the host plant range by the European *Brahmaea* closely matches that of its ally *B. ledereri*, which in the wild was recorded from *Fraxinus "excelsior"* L. and *Phyllirea latifolia* and in captivity accepted other Oleaceae (Korb 1899; De Freina 1985). The larvae show a gregarious behavior; in accordance with the observations made by Spicciarelli (2013, 2014) about the feeding strategies of caterpillars, they appear to have a “nomadic foraging” behavior (Fitzgerald & Peterson 1988).

Eggs are laid in clusters on tree trunks, from which the larvae spread and reach the tip of relevant trees and bushes which are consumed first. Subsequently, they descend onto lower twigs and then, when a given size is attained, they disperse onto other plants even at remarkable distance (Spicciarelli 2014). The attitude of consuming the host plants starting from the uppermost shoots is a behavioral trait shared with its geographically closest relative, the Anatolian-Iranian *Brahmaea ledereri* (Nässig personal communication, 1985).

Geographic distribution

In figure 8 the few localities in Southern Italy where *Brahmaea (Acanthobrahmaea) europaea* is known to occur are listed; data were obtained from Hartig (1963, 1997), Parenzan (1978), Bertaccini et al. (1995) and personal observations. Rumors that the species had been collected by amateurs or students in far apart areas of region Campania and even Gargano promontory in Apulia (e.g. Parenzan & Porcelli 2006) were never formally corroborated. In this respect, it is worth noting that samplings run in fully suitable biotopes in Daunia Mts in Northern Apulia (e.g. Catola Valley near Volturara Appula, Foggia Province) regularly revealed all species accompanying the European *Brahmaea* where it thrives in the Ofanto Valley with the exception of the brahmaeid itself.

Survey methods

Dedicated monitoring methods for *Brahmaea (Acanthobrahmaea) europaea* have not been developed. As larvae

are very difficult to locate in the wild they are not suitable for monitoring the species. In contrast, adults are easily recorded at artificial lights so the generic monitoring method described by Trizzino et al. (2013) for nocturnal Lepidoptera may be easily applied to assay distribution, abundance and demographic fluctuations of populations of the species.

Conservation status and threats

At present, *Brahmaea (Acanthobrahmaea) europaea* is not protected by law and it is not included in CITES and Habitat Directive annexes, though concern about its long-term survival was often raised (Zilli 1991; Spicciarelli 2000, 2004, 2006) and it was explicitly recorded in some red lists (e.g. Spicciarelli 2002). Nevertheless, in 1971 the Riserva Naturale Orientata Grotticelle (Fig. 2) was established by the former Italian Ministry of Agriculture and Forestry in order to preserve the possibly most relevant colony of the species so far identified, that representing probably the first Nature Reserve in the World to be specifically designed to protect an insect species. Interestingly, the Italian Postal Service (Poste Italiane) dedicated to *B. europaea* a postage stamp (Fig. 10), issued in August 1996 within the framework of the XX International Congress of Entomology held in Florence (Zilli 1996).

During the preparation of the management plan of the Grotticelle Nature Reserve a number of threats to the survival of the species could be identified, despite the lack of knowledge about its ecological requirements (Audisio et al. 2012; Spicciarelli 2013).

Generally speaking, menaces to populations of the European *Brahmaea* may be sorted among two orders of scale, that is local, viz. at the level of individual topodemes, and regional.

At the broadest level, habitat fragmentation undoubtedly represents the most worrying variable. The European *Brahmaea* is a strictly mesophilous woodland species the persistence of which is clearly linked to the presence of suitable, unaltered woodland biotopes. In fact, no individual strays have ever been recorded substantially far apart from woods. Furthermore, despite an evergreen mediterranean shrub like *Phyllirea latifolia* enters the dietary spectrum by the caterpillars, no population of the species has ever been located in both low and tall mediterranean maquis, where *Phyllirea* spp. are among the main dominant plant species shaping the vegetation. The region Basilicata, once known as Lucania, which after the most plausible etymology took name from *lucus* (the sacred wood of Romans) to stress its extensive forest coverage, faced a long history of deforestation. Spanning from classical to recent times, woodlands of Basilicata were subject to massive cuttings to get wood for building fleets, heating and support manufacturing industry, to clear spaces for the cultivation of wheat and other cereals, contrast diffusion

of banditry or producing wooden ties for the rail industry (e.g. Morano 1981; McNeill 1992; Spicciarelli 2004; Lamendola 2008). In addition to the general logging which already led to a dramatic reduction and fragmentation of forested areas, and regrettably is still partly ongoing, it must be also considered that in evident consequence of the mesohygrophyly shown by one of its main host plants, the narrow-leafed ash, populations *B. europaea* are somewhat associated with fluvial axes, which is right were a concentration of infrastructures such as roads, railways, industrial plants and commercial warehouses is increasingly being settled. The loss of connectivity between woodland fragments hosting the species and their reduced size are likely to turn as the most detrimental factors affecting wealth and persistence of the *Bramea* populations. Furthermore, it was shown both with light surveys and after mapping of host plants in the Grotticelle Reserve that the distribution of the individuals and suitable environmental patches across woodlands is far not uniform (Spicciarelli 2014), so that the very presence of the species in the woodland fragments where it occurs is actually a subset of the wooded areas themselves.

At a local scale, the natural behavior and activities of *B. europaea* are evidently disrupted by light pollution when this extends over the home range by the adults; in fact, the species is markedly phototropic and comes freely to artificial lights, as Longcore & Rich (2004) generally stressed for moth populations. The State Forestry Corp pursues a careful policy of management of artificial lights in some minor railway stations around the Grotticelle Reserve (e.g. Aquilonia Scalo, Monticchio Scalo). To enhance protection of the species it would thence be essential to employ lamps with low impact on the flight paths by *B. europaea* and permanently reduce light pollution in proximity of all known populations of the moth.

The alteration or simply an improper management of the environment may also affect the abundance and distribution of the host plants; for example, the clearing of the forest undergrowth for fire prevention may lead to a drastic reduction of the bushes of Oleaceae supporting the moth populations, so for the grazing by sparse cattle in woodland habitats.

A traditional threat for *B. europaea* is represented by the collection of individuals; in fact, this is a so localized and handsome species that is highly coveted by amateur entomologists.

Last but not least, another menace to *Bramea* populations is represented by the increase of wild boar populations, chiefly in protected areas, with individuals rooting anything edible out from soils. As a matter of fact, insects, among which pupae of large sized moths, are known to enter the diet of the wild boar (Genov 1981; Schley & Roper 2003), and the presence of digested pupae of *B. europaea* was recently confirmed in excrements of wild boars collected under stands of narrow-leafed ash in the Grotticelle Reserve (Spicciarelli 2014), thus demonstrating a clear impact

that the foraging behavior of these animals may have on the persistence of populations of the moth at a local scale.

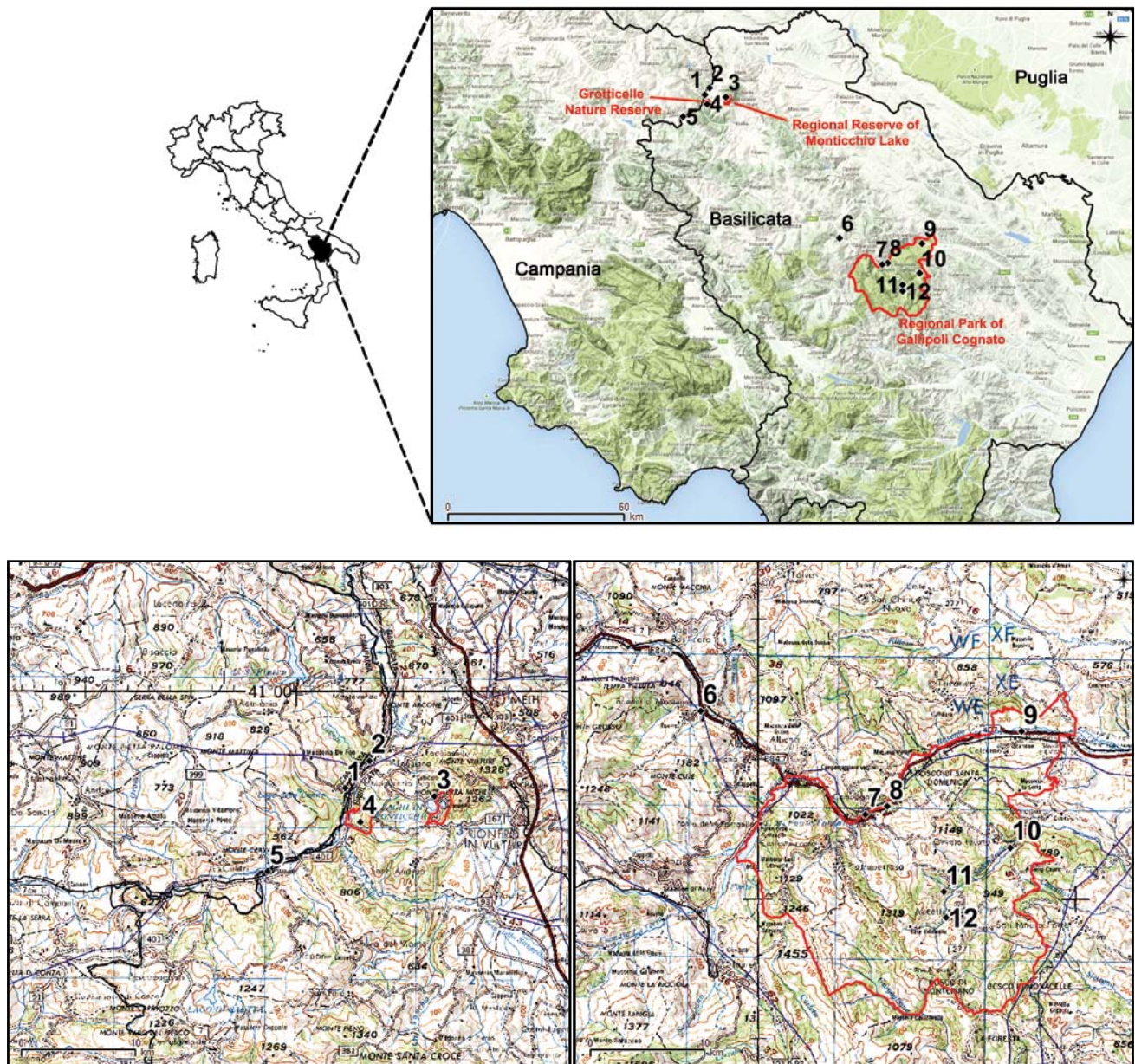
Measures for conservation

Considering its extremely restricted range and known ecological requirements by the species every possible effort should be addressed to increase extension and connectivity of environmental patches actually or potentially hosting the species. In fact, with such a fragmented pattern of suitable biotopes even a small increase of the forested surface may turn out essential in ensuring steadiness or recovery of *Bramea* populations. In any case, it is highly recommended that regional forestry management plans are reviewed focusing on the presence of this so valuable moth, so that at least no logging activity may be undertaken without a prior assessment about its putative occurrence in sites allotted for forest exploitation. In positive cases, a redefinition of the boundaries of forest plots and density of tree cuttings should clearly take place by leaving intact stands of the *Bramea* host plants inside respect zones of adequate width.

An integrate management and protection of forested areas currently shared between different administrative bodies should also be put in force. This is particularly true for the Ofanto Valley which is so far the area where most abundant *Bramea* populations were found but marks the boundary between two different provinces (Avellino and Potenza) pertaining to two distinct regions (Campania and Basilicata) with fairly different forestry policies.

Following the IUCN guidelines (IUCN 2014), *B. europaea* should be assigned the EN (Endangered) category of risk, as based on the relevant application of Criterion B [B1ab(iii) + B2 ab(iii)]. This proposal combines its Extent of Occurrence (the area of a virtual polygon laid out so as to join all its known sites of occurrence) of less than 5,000 Km² (in fact, less than 2,000 Km²; Fig. 6); an Area of Occupancy (calculated using a contour square area of 2x2 Km² for each of the known localities) of less than 500 Km² (in fact, less than 50 Km²); the markedly fragmented structure of its geographic range (Fig. 6); the total number (12) of the so far known localities, some of them being very close to each other, and clustered in only three main locations; and the observed decline in habitat quality by most of the known sites of occurrence, mostly due to recent diffusion of invasive populations of wild boars in two out of the three main locations (Vulture and Gallipoli-Cognato protected areas).

Present-day unfeasibility to broaden the list of protected species in the EU Habitats Directive (HD) by member countries hinders conservation of this rare and threatened species. However, as part of its Regulatory Fitness and Performance Programme (REFIT), the European Commission is undertaking a "Fitness Check" of the EU nature legislation, the Birds Directive and the Habitats Di-



ID	Locality	Province	Reference
1	Aquilonia (Rail Station)	AV	Parenzan 1978; Audisio et al. 2012; Spicciarelli 2013, 2014
2	Monticchio (Rail Station)	PZ	Parenzan 1978; Spicciarelli 2004
3	Monticchio lakes, Forest Station	PZ	Hartig 1963; Spicciarelli 2014
4	Grotticelle Nature Reserve	PZ	Hartig 1963; Audisio et al. 2012; Spicciarelli 2013, 2014
5	Rapone (Rail Station)	PZ	Bertaccini et al. 1995
6	Brindisi di Montagna (Rail Station)	PZ	Parenzan 1978
7	Campomaggiore (Rail Station)	PZ	Parenzan 1978
8	Gallipoli Forest, near Campomaggiore	PZ	Bertaccini et al. 1995
9	Calciano (Rail Station)	MT	Parenzan 1978
10	Oliveto Lucano	MT	Bertaccini et al. 1995
11	Salandrella Valley	MT	Bertaccini et al. 1995
12	Accettura	MT	Bertaccini et al. 1995

Fig. 8 – Known distribution area of *Brahmaea (Acanthobrahmaea) europaea* Hartig, 1963 with list of known sites for the species.



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Figs 9-10 – 9, Federico Hartig and Marina Cobolli at Grotticelle N.R., June 1970 (photo by V. Sbordoni); 10, the stamp dedicated to *B. europaea* issued by Poste Italiane in August, 1996.

rective, which will involve a comprehensive assessment on whether or not the current regulatory framework is “fit for purpose” (EU Commission 2014), with perspectives of a possible reappraisal at the European level of the whole process of inclusion, use and management of the HD’s species list.

Given the aforementioned attribution of EN Category of Risk, any measures aimed at reducing the impact of threats reviewed above has also to be recommended. The extent of light pollution may easily be controlled after adoption of artificial lights little luring for moths such are sodium vapor ones, employing fixtures technically suited for preventing dispersion of rays other than directly on ground and avoiding unnecessary lighting. Due to the ruling of CITES, mostly designed to prevent illegal trade than protecting species in the ground, prevention of collection of individuals in the wild may be enforced by laws at regional scale and in any case after simple measures preventing access to roads leading to forest stands hosting *Braema* populations.

More difficult appears to be control of sounders of wild boars resting and foraging in sites where caterpillars pupate, this being a factor in need of careful consideration for any realistic action plan aimed at preserving the moth. In addition to proper analysis of the last variable, the necessity to increase knowledge about the bionomics, ecological requirements, demographic parameters and genetic structure of populations of *Brahmaea (Acanthobrahmaea) europaea* cannot be underestimated if we are committed to protect one of the most interesting and valuable elements of the whole European fauna.

In this framework, a project of our research group is being launched (2015-2017) with the aim to evaluate by

means of integrative methods the population size of each *B. europaea* demes. Classical Capture-Mark-Recapture (CMR) protocols for species monitoring will be combined with molecular procedures aimed to assess effective population size using *F*-statistics, which describes the statistically expected level of heterozygosity in a population (Holsinger & Weir 2009), and a modelling of both the ecological niche and distribution of this endangered taxon will be performed (see Barve et al. 2011).

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