

# Current distribution raises concerns on the conservation of *Tettigetta mariae* (Quartau & Boulard, 1995) (Hemiptera: Cicadoidea) in Portugal

Vera L. Nunes<sup>i</sup>, Raquel Mendes<sup>ii</sup>, José Alberto Quartau<sup>iii</sup>, [Paula Cristina Simões](mailto:Paula.Cristina.Simoes@fc.ul.pt)<sup>iv</sup>

Faculdade de Ciências da Universidade de Lisboa, Departamento de Biologia Animal e Centro de Biologia Ambiental, Computational Biology and Population Genomics Group, Lisboa, Portugal.

<sup>i</sup> [vnunes@fc.ul.pt](mailto:vnunes@fc.ul.pt)

<sup>ii</sup> [raquelgmendes@gmail.com](mailto:raquelgmendes@gmail.com)

<sup>iii</sup> [jaquartau@fc.ul.pt](mailto:jaquartau@fc.ul.pt)

<sup>iv</sup> [pcsimoes@fc.ul.pt](mailto:pcsimoes@fc.ul.pt); corresponding author

## Abstract

*Tettigetta mariae* (Quartau & Boulard, 1995) is a small-sized cicada species endemic to the southern Iberian Peninsula, whose ecology and current distribution is still poorly known. As a result of recent fieldwork in southern Portugal and Spain we report here an update on the distribution range and habitat preferences of *T. mariae*. The distribution of this species is mostly restricted to the coast of central Algarve (Portugal) and Huelva province (Spain), being heavily fragmented and discontinuous. The species appears to be habitat-specific, with a clear preference for habitat with stone pine and at a close distance from the sea. The conservation of *T. mariae* populations is threatened, particularly in Algarve, by anthropogenic changes in land use and habitat loss and by interspecific competition with its sibling and wider distributed *T. argentata*. We advocate that *T. mariae* should be considered as an endangered species and should be subjected to annual monitoring.

**Keywords:** Cicada, conservation, distribution range, habitat, land use, Portugal.

## Resumo

*Tettigetta mariae* (Quartau & Boulard, 1995) é uma espécie de cigarra de pequeno porte endémica do sul da Península Ibérica, com ecologia e distribuição ainda pouco conhecida. Em resultado de intensivo trabalho de campo desenvolvido recentemente no sul de Portugal e Espanha, reportamos aqui uma atualização da distribuição e preferências de habitat de *T. mariae*. A distribuição desta espécie encontra-se praticamente restrita à costa da região central do Algarve (Portugal) e da província de Huelva (Espanha), sendo bastante fragmentada e descontínua. Esta espécie parece ser especialista em relação ao habitat, com uma clara preferência por zonas com pinheiro manso e perto do mar. A conservação das populações de *T. mariae* está ameaçada, principalmente no Algarve, por mudanças antropogénicas no uso do solo e perda de habitat e pela competição com a espécie-irmã mais largamente distribuída, *T. argentata*. Defendemos que *T. mariae* seja considerada uma espécie ameaçada e sujeita a monitorizações anuais das suas populações.

**Palavras-chave:** Cigarra, conservação, área de distribuição, habitat, uso do solo, Portugal.

## Introduction

Cicadas (Hemiptera, Cicadoidea) are common in Mediterranean countries and quite famous for their conspicuous calling

songs in the summer. Cicadas have long larval stages spent underground and a short winged adult stage that lasts for a few weeks (Claridge 1985, Boulard & Mondon 1995, Williams & Simon 1995).

The calling songs are produced by adult males to attract females for reproduction and are usually species-specific (Boulard 2006). The biology and accurate distribution range of most Mediterranean cicadas is still poorly known. In fact, several cicada species were recognized only recently, highlighting the importance of the Iberian Peninsula as a hotspot for cicada diversity and endemism (Boulard 1982, 2000, Quartau & Boulard 1995, Puissant & Sueur 2010).

A recent study confirmed the occurrence of 13 cicada species in Portugal (Sueur *et al.* 2004). Most Portuguese cicadas have currently a scattered distribution, which in some cases makes them extremely vulnerable. Some cicadas are believed to have very restricted distribution ranges but extensive field surveys are missing and accounts of occurrence in literature mostly result from the accumulation of singular observations by different authors.

*Tettigettalna mariae* (Quartau & Boulard, 1995) is a small-sized cicada that was described from Quinta do Lago, Algarve, and was thought to be endemic to this region of Portugal, until its recent discovery in the province of Huelva, in Spain (Simões *et al.* 2013). This species may occur in sympatry with other *Tettigettalna* species, namely *T. argentata* (Olivier, 1790) and *T. josei* (Boulard, 1982) (Quartau & Boulard 1995, Sueur *et al.* 2004, Nunes *et al.* 2014). *Tettigettalna mariae* and its sibling *T. argentata* are morphological and genetically very similar but their calling songs are distinctive and species-specific (Quartau & Boulard 1995, Nunes *et al.* 2014, Mendes *et al.* 2014). As an outcome from intensive fieldwork for species of genus *Tettigettalna* in both southern Portugal and Spain during the summers of 2011-2013, we report here an update on the distribution range and habitat preferences of *T. mariae*. The results confirm the restricted and fragmented distribution of the species, being particularly vulnerable to habitat loss in Algarve, where human pressure is higher.

### Materials and methods

Several field surveys were conducted in the southern Iberian Peninsula (regions of Algarve and Andalusia) from the end of June until mid-August during the summers of 2011-2013. The fieldwork took place from 10:00 am to 07:00 pm with sunny weather and with temperatures ranging from 24° to 39°C. Initial searches in 2011

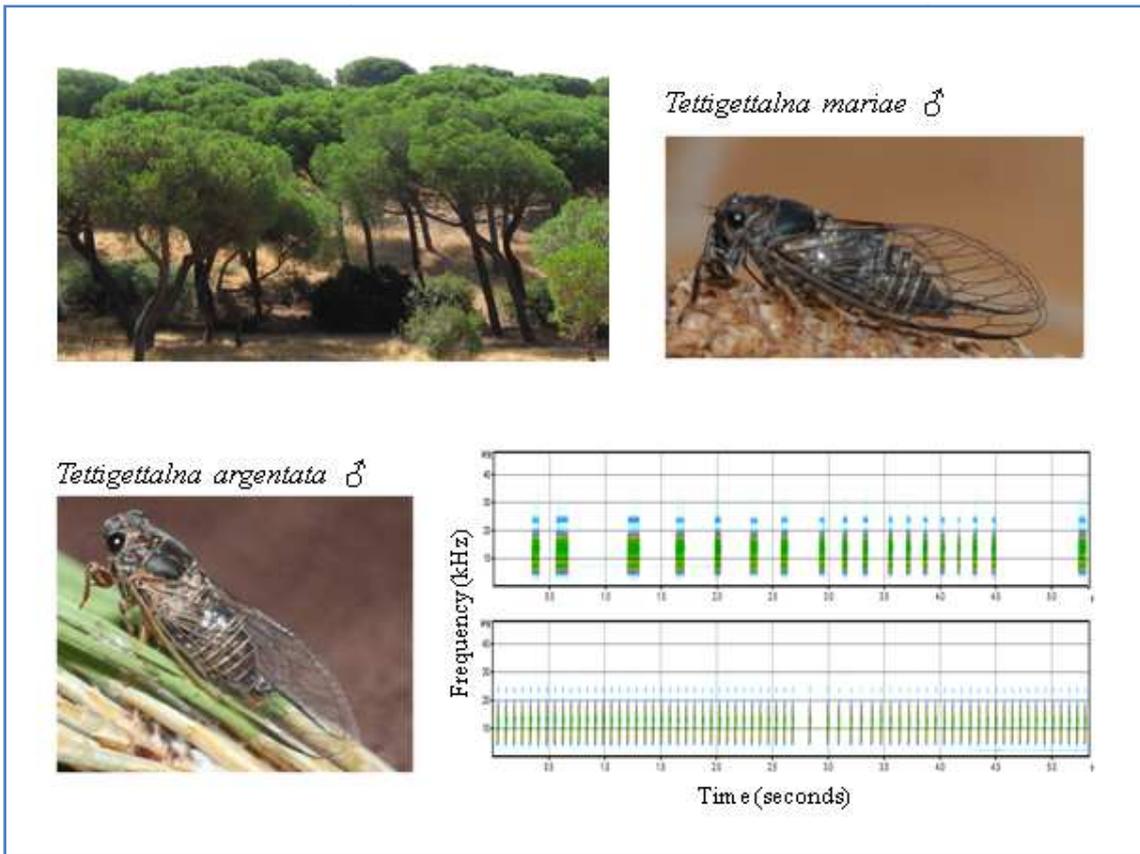
were conducted by driving a car at low speed to allow the detection of the calling males. In 2012 and 2013, searches were targeted to areas of potentially suitable habitat. Specimens were located and identified through their species-specific calling song (Fig. 1). Geographical coordinates of each location were determined with a GPS (Garmin, Oregon series 550t). Several male songs were recorded using a Marantz PMD 661 Portable SD recorder (20Hz – 24kHz) connected to a Telinga Pro 7 Dat-mic microphone (Twin Science) following the procedures given in Simões *et al.* (2000). Species confirmation was accomplished with time and frequency analysis of sound recordings using the software Avisoft Sas-Lab Pro (Specht 2012) as described in Simões *et al.* (2013).

### Results

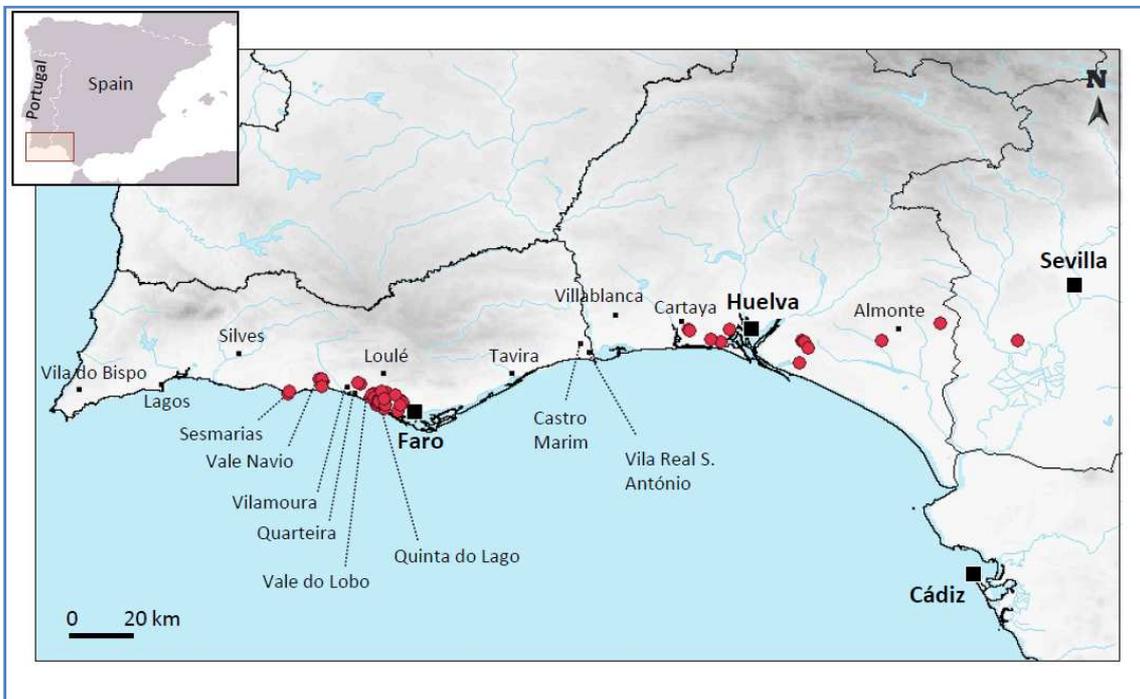
Field prospections in Algarve were at first conducted near the coast, along road N125, from the Atlantic west coastline, near Vila do Bispo, until river Guadiana bank at Vila Real de Santo António. Singing males of *Tettigettalna mariae* were found only in central Algarve, confirming its presence in all locations previously reported in the literature (Sueur *et al.* 2004), except for Castro Marim. Searches in and around Castro Marim were unsuccessful in both 2011 and 2012 summers. We refined our fieldwork in central Algarve to understand the real extent of the species distribution. *T. mariae* was found in several locations around Quinta do Lago, Vale do Lobo, Quarteira, Vale Navio and Vale Judeu (Fig. 2). We found Sesmarias as the westernmost location and the pine woods at the west vicinity of Faro city as the easternmost occurrence (Long. 8°18' to 7°57'W). The latitudinal range is small (37°00' to 37°07'N). It goes from the coastline and does never exceed 7km inland along its range.

In Spain, the occurrence of the species beyond the east bank of Guadiana river, in the province of Huelva (Andalusia), was first noticed in 2012 (Simões *et al.* 2013) and confirmed in the summer of 2013. Our searches were extended to other Andalusian provinces and Murcia, but *T. mariae* distribution remains restricted to the province of Huelva and partially to the province of Sevilla (Fig. 2), between Cartaya and Coria del Rio.

We noted a remarkable coincidence between the distributions of *T. mariae* and



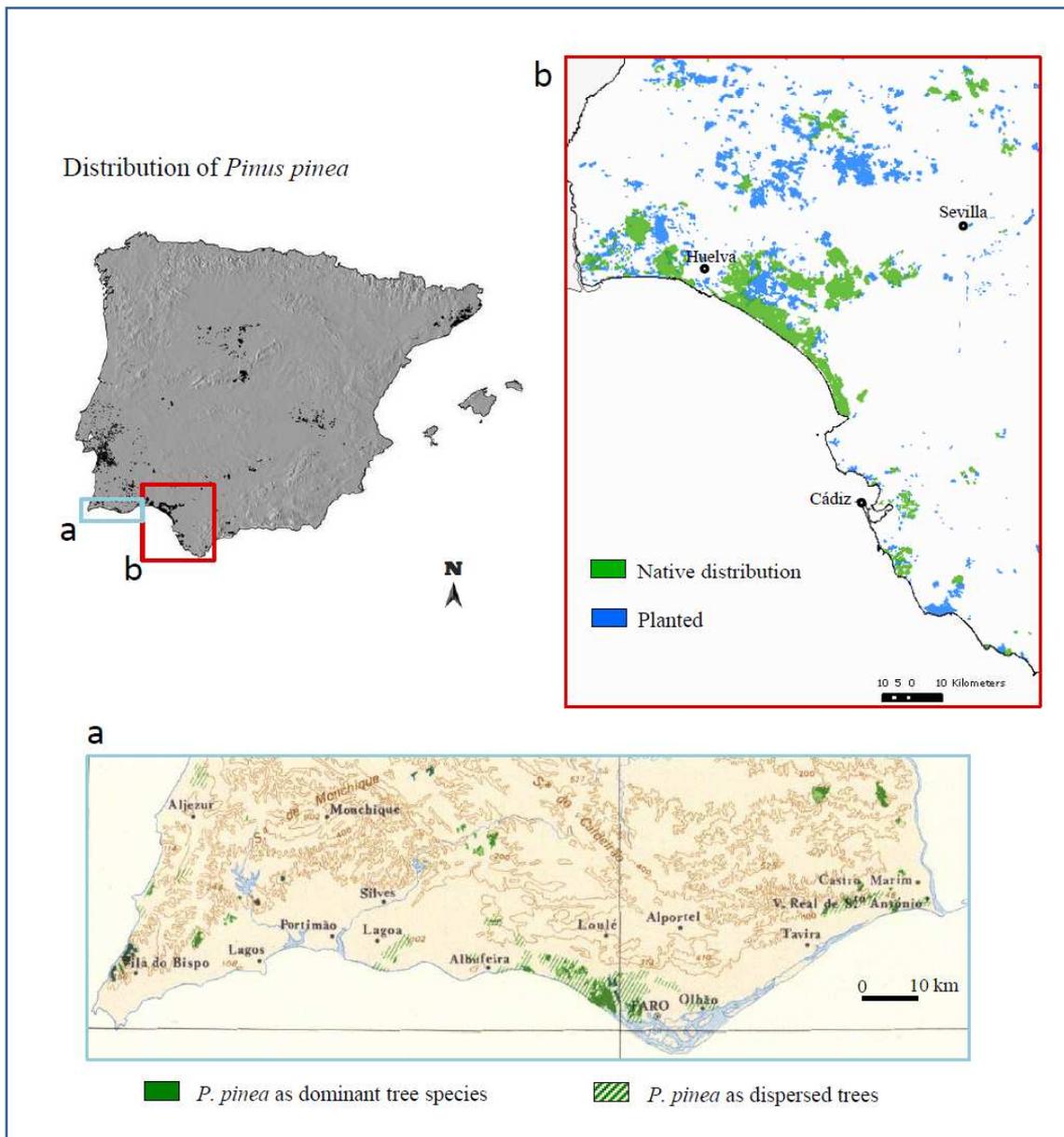
**Figure 1.** Sonograms (bottom right) of typical male calling song of *Tettigettalna mariae* and from its sibling *Tettigettalna argentata*. The stone pine (*Pinus pinea*) wood photo was taken in July 2013, near Cartaya (Huelva, Spain) and corresponds to the location where the largest population of *T. mariae* was found so far.



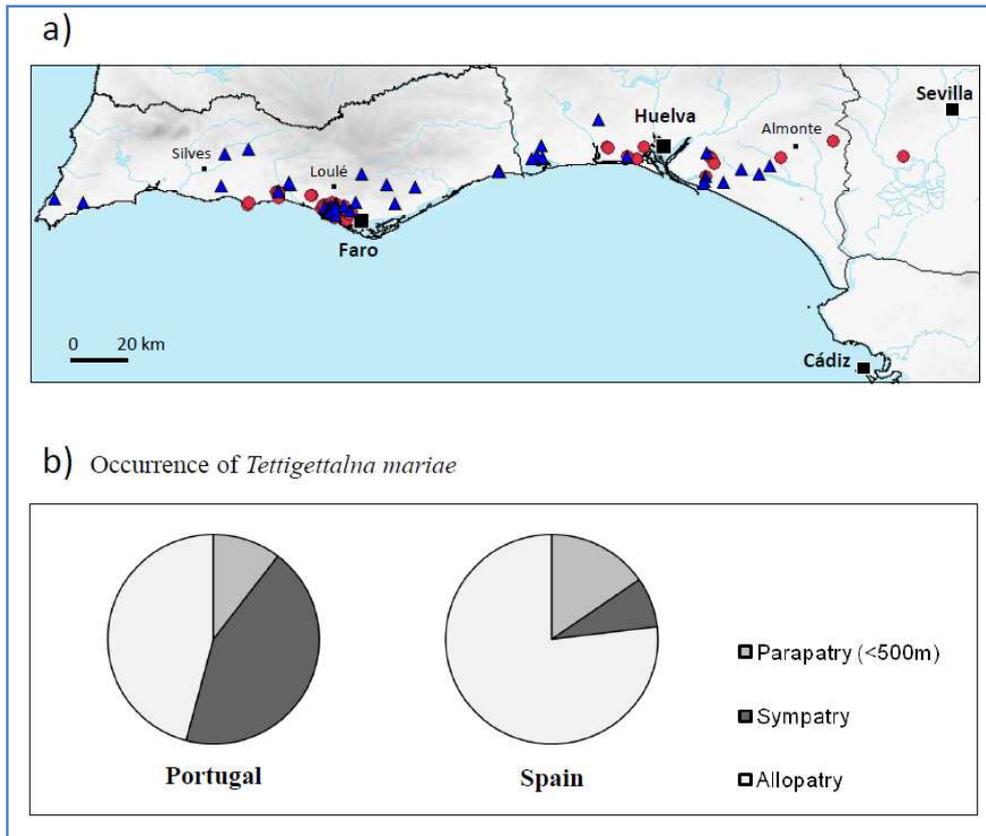
**Figure 2.** Map of the southwest of the Iberian Peninsula with occurrence records for *Tettigettalna mariae* in the summers of 2011-2013.

of stone pine (*Pinus pinea*) in south western Iberia (Fig. 3). These pine woods are mostly present in sandy soils near the coast. At some locations, *T. mariae* males were found singing on almond (*Prunus dulcis*) or carob trees (*Ceratonia siliqua*), in shrubs such as acacia (*Acacia longifolia*), ladanum (*Cistus ladanifer*) or common blackberry (*Rubus fruticosus*) and on a small abandoned orange (*Citrus sinensis*) tree crop. In all these cases, patches of stone pine forest or dispersed or isolated stone pines could be found in the immediate vicinity. The majority of males were usually perched on pine

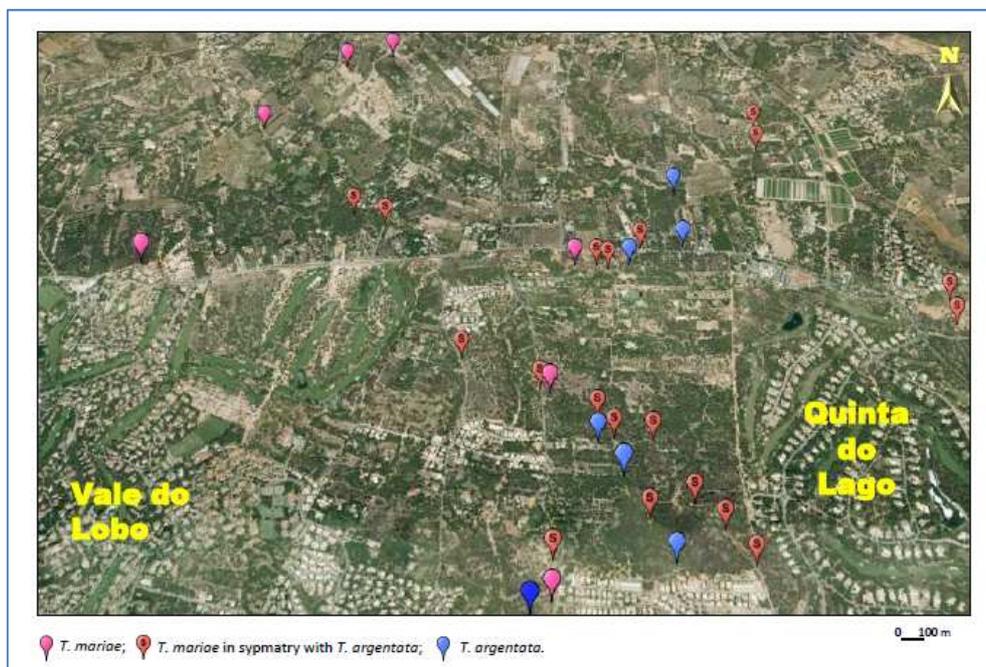
branches while singing and the location with the highest number of *T. mariae* males singing in allopatry was found in Spain, within a stone pine forest near El Portil (Lat. 37°13'32.0"N, Long. 07°02'05.4"W). This forest was partially planted, with *T. mariae* singing on relatively young trees, with 3-4m height and about 2m wide crowns, producing little shade. Shrubs and ladanum (*C. ladanifer*) in particular were abundant under pine trees, but *T. mariae* males were consistently singing perched on pine crowns.



**Figure 3.** Distribution of stone pine (*Pinus pinea*) in the Iberian Peninsula (source: Benito Garzón 2006, available at [www.uam.es/proyectosinv/Mclim/results.html](http://www.uam.es/proyectosinv/Mclim/results.html)). a) Distribution of stone pine in Algarve (Portugal). The map dates from 1980 and is available at <http://sniamb.apambiente.pt/webatlas/>. b) Distribution of stone pine in the southwest of Spain (F. J. Auñón and D. Sanchez de Ron, available at [http://iniagis.inia.es/Pinus\\_pinea/](http://iniagis.inia.es/Pinus_pinea/)).



**Figure 4.** a) Distribution map of *Tettigetta mariae* (light red circles) overlapped with occurrence points of the sibling species, *T. argentata* (blue triangles).  
 b) Pie chart of occurrence points of *T. mariae* in Portugal (n = 48) and Spain (n = 13) classified as allopatric or as sympatric or parapatric with *T. argentata*.



**Figure 5.** Land cover in the area between Vale do Lobo and Quinta do Lago, in central Algarve coastline, where most occurrence points of *Tettigetta mariae* were registered (source: © Google Earth). Most of the area is heavily humanized, with touristic villages, golf courses and unnatural green landscapes. Isolated stone pines are maintained in humanized areas for its ornamental value. Small forest areas with natural stone pine or mixed stone and maritime pine persist between Vale do Lobo and Quinta do Lago and harbour sympatric and parapatric populations of *T. mariae* and *T. argentata*.

*T. mariae* was found in sympatry or parapatry (< 500m) with singing males of *T. argentata* in a high proportion of occurrence points (Fig. 4), particularly in Algarve, around Vale do Lobo and Quinta do Lago (Fig. 5). The coastline of Algarve is heavily urbanized, and most habitat patches where *T. mariae* occurs are surrounded by touristic villages or golf courses, mainly in Vale do Lobo and Quinta do Lago (Fig. 5). The occurrence of *T. mariae* in Algarve is particularly sparse between the localities of Sesmarias and Vale do Lobo. The occurrence of stone pine in this area is also quite dispersed, the landscape being dominated by agriculture (small crops of almond, carob, fig or olive trees), uncultivated scrublands and human occupation.

## Discussion

The acoustic surveys of 2011-2013 confirmed that the distribution of *Tettigetta mariae* is currently restricted to the southwest coast of the Iberian Peninsula and is heavily fragmented and discontinuous. The species appears to be habitat-specific, with a clear preference for habitat with stone pine and at a close distance from the sea. The distribution of stone pine in the Iberian Peninsula is fragmented as well and mainly found on coastal and inland sands or on very poor soils (García del Barrio et al. 2013). The province of Huelva harbours the largest area of stone pine forest (Fig. 3) but this Mediterranean pine species is presently absent in more than 60% of the landscapes or biogeoclimatic classes that it could inhabit in Spain (García del Barrio et al. 2013). Paleocological evidence suggests that the distribution of stone pine was more extensive in the past (Martínez & Montero 2004, Benito Garzón et al. 2007, Valbuena-Carabaña et al. 2010). Reconstructions of past distribution of stone pine for 6000 years before present indicate that it was nearly continuous between central Algarve and Huelva (see Benito Garzón 2006). The present fragmentation in *T. mariae*'s distribution probably reflects the effect of long term decline of suitable habitat.

Previous records of *T. mariae* in Castro Marim from late nineties (Sueur et al. 2004) were not confirmed by our surveys in two consecutive years. The two main distribution areas (central Algarve and Huelva) are now separated by nearly 70 kilometers. We predict that this distance is large enough to keep populations of both areas nearly or completely isolated.

Simões & Quartau (2007) determined through mark-recapture that males from a large-size cicada (*Cicada orni*) survive for about two weeks and their flight dispersal does not exceed 150m. Instead of investing in dispersal, males of *C. orni* tend to remain close to their emergence site and maximize their chances of mating with a strong singing activity. It is likely that *Tettigetta* cicadas use a similar strategy and the dispersal of both sexes is expected to be small.

Habitat loss and fragmentation are considered great threats to biodiversity. However, not all species are equally vulnerable to extinction risk (reviewed by McKinney 1997). This uneven vulnerability probably results from the specific ecological attributes/life-traits of a species, which determine how well it is able to withstand the external threats to which it is exposed (McKinney 1997). In addition, a combination of more than one of these traits further increases a species risk of extinction (Lawton 1994). For instance, species that are both rare and specialized can be especially vulnerable to extinction (Davies et al. 2004).

Considering the distribution update and habitat preference reported here, we consider that *T. mariae* is highly vulnerable to habitat loss caused by changes in land use or forest fires, which often jeopardize pine woods during the summer, when adult cicadas have their breeding season and lay their eggs on trees or bushes. This risk is greater in Algarve, where the anthropogenic pressure is more intense, than in southern Spain, where large patches of stone pine are maintained as forest areas. However, both in Portugal and Spain, *T. mariae* populations are frequently overlapped or surrounded by populations of *T. argentata*, a more generalist species and with a much wider distribution. Species-specific calling songs are probably determinant to restrict gene flow between these sibling species. However, according to sequence data from the mitochondrial gene cytochrome oxidase I (Nunes et al. 2014), there is no genetic differentiation of *T. mariae* from *T. argentata* populations surrounding or overlapping *T. mariae*'s distribution range. In fact, some haplotypes are shared between these species and it remains unclear whether haplotype sharing is due to past or recent introgression or to incomplete lineage sorting. Interspecific competition between sibling species with similar requirements might represent an

additional threat for the persistence of *T. mariae*.

We advocate that *T. mariae*, being one of the rarest Portuguese cicadas and a southwest Iberian endemism, should be considered as an endangered species. Since their populations are in decline, we believe that measures for their conservation should be taken and it should be considered an endangered species in the category of vulnerable (VU). Annual monitoring for *T. mariae* populations should be implemented at more sensitive areas such as Vale do Lobo and Quinta do Lago, as well as in suitable habitats near Castro Marim, to evaluate the species ability to expand its range and recolonize from adjacent areas in Spain. The forests of pine should be preserved, with occasional planting of new trees and the herbaceous layer should be maintained whenever possible. If removed, as a fire prevention method, it should only be done in mosaic and without soil plowing, which may expose the underground nymphs to extinction (Quartau 2009, Quartau & Mathias 2010).

#### Acknowledgments

This study was financially supported by the project PTDC/BIA-BIC/115511/2009 of the Portuguese Foundation for Science and Technology (FCT). We thank Bruno M. Novais for help during fieldwork.

#### References

- Benito Garzón M, 2006. El efecto del cambio climático sobre las distribuciones de los bosques ibéricos: Pasado, Presente y Futuro (Phd dissertation). Universidad Autónoma de Madrid, Madrid, Spain.
- Benito Garzón M, Sánchez de Dios R, Sáinz Ollero H, 2007. Predictive modelling of tree species distributions on the Iberian Peninsula during the Last Glacial Maximum and Mid-Holocene. *Ecography* 30: 120-134.
- Boulard M, 1982. Les cigales du Portugal, contribution à leur étude (Hom. Cicadidae). *Ann Soc entomol Fr* 18: 181-198.
- Boulard M, 2000. Description de quatre *Tettigetia* ibériques nouvelles. *EPHE, Biologie et Évolution des Insectes* 13: 133-143.
- Boulard M, 2006. Acoustic signals, diversity and behaviour of cicadas (Cicadidae, Hemiptera), pp 331-349. In: S. Drosopoulos & M. F. Claridge (Eds). *Insect Sounds and Communication: Physiology, Behaviour, Ecology, and Evolution*. CRC Press, Taylor & Francis Group, Boca Raton FL, USA.
- Boulard M, Mondon B, 1995. Vies et memoires de cigales. Provence, Languedoc, Méditerranée. Equinoxe, Barbentane.
- Claridge M, 1985. Acoustic signals in the Homoptera: behavior, taxonomy, and evolution. *Ann Rev Entomol* 30: 297-317.
- Davies KF, Margules CR, Lawrence JF, 2004. A synergistic effect puts rare, specialized species at greater risk of extinction. *Ecology* 85: 265-271.
- García del Barrio JM, Auñón F, Sánchez de Ron D, Alía R, 2013. Assessing regional species pools for restoration programs in Spain. *New Forest* 44: 559-576.
- Lawton JH, 1994. Population dynamic principles. *Philos T Roy Soc B* 344: 61-68.
- Martínez F, Montero G, 2004. The *Pinus pinea* L. woodlands along the coast of South-western Spain: data for a new geobotanical interpretation. *Plant Ecol* 175: 1-18.
- McKinney ML, 1997. Extinction vulnerability and selectivity: Combining ecological and paleontological views. *Annu Rev Ecol Syst* 28: 495-516.
- Mendes M, Nunes VL, Quartau JA, Simões PC, 2014. Patterns of acoustic and morphometric variation in species of genus *Tettigetia* (Hemiptera: Cicadidae): sympatric populations show unexpected differences. *Eur J Entomol* 111: 429-441.
- Nunes VL, Mendes R, Marabuto E, Novais BM, Hertach T, Quartau JA, Seabra SG, Paulo OS, Simões PC, 2014. Conflicting patterns of DNA barcoding and taxonomy in the cicada genus *Tettigetia* from southern Europe (Hemiptera: Cicadidae). *Mol Ecol Resour* 14: 27-38.
- Puissant S, Sueur J, 2010. A hotspot for Mediterranean cicadas (Insecta: Hemiptera: Cicadidae): new genera, species and songs from southern Spain. *Syst Biodivers* 8: 555-574.
- Quartau JA, 2009. Preventative fire procedures in Mediterranean woods are

destroying their insect Biodiversity: a plea to the EU Governments. *J Insect Conserv*, 13:267-270.

Quartau J, Boulard M, 1995. *Tettigetia mariae*, nouvelle Cigale lusitanienne (Homoptera Cicadoidea Tibicinidae). EPHE Biologie et Évolution des Insectes 7/8: 105-110.

Quartau JA, Mathias ML, 2010. Insects of the understorey in Western Mediterranean forest landscapes: a rich biodiversity under threat, pp 133-142. In: E.L. Harris & N.E. Davies (Eds.). *Insect Habitats: Characteristics, Diversity and Management*. Nova Science Publishers, Inc. New York, USA.

Simões P, Boulard M, Rebelo M, Drosopoulos S, Claridge M, Morgan J, Quartau J, 2000. Differences in the male calling songs of two sibling species of *Cicada* (Hemiptera: Cicadoidea) in Greece. *Eur J Entomol* 97: 437-440.

Simões PC, Nunes VL, Mendes R, Quartau JA, 2013. First record of *Tettigetia*

*mariae* Quartau & Boulard 1995 (Insecta: Hemiptera: Cicadoidea) in Spain. *Biodivers Data J* 1: e978. doi: 10.3897/BDJ.1.e978

Simões PC, Quartau JA, 2007. On the dispersal of males of *Cicada orni* in Portugal. *Entomol Gen* 30: 245-252.

Specht R, 2012. *Avisoft-SASLab Pro*. Berlin: Sound analysis and synthesis laboratory.

Sueur J, Puissant S, Simões PC, Seabra S, Boulard M, Quartau JA, 2004. Cicadas from Portugal: revised list of species with eco-ethological data (Hemiptera: Cicadidae). *Insect Syst Evol* 35: 177-187.

Valbuena-Carabaña M, López de Heredia U, Fuentes-Utrilla P, González-Doncel I, Gil L, 2010. Historical and recent changes in the Spanish forests: a socio-economic process. *Rev Palaeobot Palyno* 162: 492-506.

Williams KS, Simon C, 1995. The ecology, behavior, and evolution of periodical cicadas. *Annu Rev Entomol* 40: 269-295.