SHORT COMMUNICATION

**First report of the invasive *Reticulitermes flavipes* (Kollar, 1837)
(Blattodea, Rhinotermitidae) in the Canary Islands**

David Hernández-Teixidor^{1,2}, Daniel Suárez^{1,3}, Javier García^{1,2} & David Mora⁴

¹ Departamento de Biología Animal, Edafología y Geología. Sección de Biología. Facultad de Ciencias. Universidad de La Laguna. Campus de Anchieta. 38206. San Cristóbal de La Laguna, Tenerife, Spain.

² Grupo de Investigaciones Entomológicas de Tenerife (GIET). San Cristóbal de La Laguna (Tenerife, Spain).

³ Island Ecology and Evolution Research Group. Instituto de Productos Naturales y Agrobiología (IPNA-CSIC). 38206. San Cristóbal de La Laguna, Tenerife, Spain.

⁴ Anticimex España. 08960. Barcelona, Spain.

Acknowledgements

We are grateful to Heriberto López and Brent Emerson (IPNA-CSIC), who provided genetic assessment, and to Pedro Oromí (ULL) for distribution data and his comments during the writing of this paper.

Correspondence

David Hernández-Teixidor, Departamento de Biología Animal, Edafología y Geología. Sección de Biología. Facultad de Ciencias. Universidad de La Laguna. Campus de Anchieta. 38206. San Cristóbal de La Laguna (Tenerife, Spain).

Email: davilhdez@ull.es

27

28 **Abstract**

29 *Reticulitermes flavipes*, one of the most harmful subterranean termite pests, is reported
30 for the first time from Tenerife (Canary Islands, Spain). Cytochrome oxidase II was
31 sequenced from five specimens in order to confirm the identification. To date, this
32 invasive species has been detected in a limited area in the northeast of the island,
33 affecting buildings, crops, and native plant species. Another colony with the identical
34 haplotype found in the southwest, 60 km away from the main population, indicates that
35 this invasive insect may be more widespread over the island.

36

37 **Keywords**

38 *Reticulitermes flavipes*, Eastern subterranean termite, invasive species, new record,
39 Canary Islands.

40

41 **Introduction**

42 Termites (Order Blattodea, Epifamily Termitoidae) are eusocial insects comprising
43 approximately 2930 described living species (Krishna, Grimaldi, Krishna, & Engel,
44 2013). They constitute three groups according to their habitat; earth-dwelling, wood-
45 dwelling, or arboreal termites, depending if their nests are in the ground (below-
46 ground or epigeal nests), inside wood or on trees, respectively (Ferreira et al., 2013).
47 Within earth-dwelling termites, the family Rhinotermitidae is of concern due to the
48 invasive character of some of its taxa worldwide, especially species of the genera
49 *Coptotermes*, *Heterotermes* and *Reticulitermes* (Evans, Forschler, & Grace, 2013).
50 Subterranean termites are characterised by cryptic nesting habits, forming extensive,
51 complex colonies with diffuse nests and multiple feeding-sites connected by tunnels

(Perdereau, Dedeine, Christidès, Dupont, & Bagnères, 2011). *Reticulitermes* is a Holarctic genus with more than 130 species described (Krishna et al., 2013), a couple of species being highly invasive worldwide. *Reticulitermes flavipes* (Kollar, 1837), native to the central and eastern USA, occupies the widest geographic distribution due to its establishment capability (Austin et al., 2012). It has been introduced into France, Germany, Austria, Italy, Terceira (Azores), Chile, Uruguay and Canada (Aber & Fontes, 1993; Austin et al., 2005; 2012; Becker, 1970; Ghesini, Pilon, & Marini, 2011; Heisterberg, 1958; Ripa & Castro, 2000; Scaduto, Garner, Leach, & Thompson, 2012). *Reticulitermes flavipes* populations cause damage to buildings and trees, generating economic losses (Khan, & Ahmad, 2018). Worldwide annual control and repair costs of subterranean termites were estimated at \$32 billion in 2010 (Rust & Su, 2012).

The invasiveness of this species outside its native range can be explained by the production of a large number of neotenic reproductives within colonies and the high fusion frequency among colonies (Perdereau et al., 2015). These characteristics favour human-mediated dispersal and increase colony foundation success (Suppo, Robinet, Perderau, Andrieu, & Bagnères, 2018). The average dispersion distance of alates is around 150 m (Baudouin et al., 2018), sometimes reaching 400 m (Shelton, Hu, Appel, & Wagner, 2006). The foraging range of a single colony covers from 1 to 90,000 m², being wider where it has been introduced (Vargo & Husseneder, 2009). It tolerates low temperatures, being able to live between 3.4 and 34.6 °C, but shows greater wood-consumption at higher temperatures (Cao & Su, 2016). Behr et al. (1972) also reported a positive correlation between wood moisture level and feeding by *R. flavipes*.

Oceanic islands have empty niches (Whittaker & Fernández-Palacios, 2007), which can facilitate the establishment of invasive alien species in island ecosystems. In fact, such species are the most significant drivers of population decline and species extinctions in

island ecosystems worldwide (Reaser et al., 2007). Oceanic islands have been the areas most invaded by termites (Evans et al., 2013), with four species reported for Macaronesia in general; four in Azores (*Cryptotermes brevis* (Walker, 1853), *Kaloterme flavicollis* (Fabricius, 1793), *Reticulitermes grassei* Clement, 1978 and *Reticulitermes flavipes*), two in Madeira (*C. brevis* and *R. grassei*) and one in Cape Verde and the Canaries (*C. brevis*). In this article we present the first report of *R. flavipes* for the island of Tenerife and for the Canary Islands, providing data about its historical spread and discussing possible impacts and dispersal routes.

Material and methods

Sampling

This study was carried out on Tenerife, the largest (2034 km²) and highest (3718 m asl) island in the Canaries, located near the centre of the archipelago. Tenerife has considerable historical architectural heritage dating from the XVI and XVII centuries in areas such as Tacoronte and La Laguna, situated in the northeast. Locations affected by the presence of *R. flavipes* have been surveyed, mainly by searching houses and public areas such as gardens and roads. The distribution data of this termite species on the island were obtained from occasional samples and data provided by a pest control company, which has maintained stations with baits from 2010 to the present. Sample specimens were collected, stored in ethanol and sequenced to confirm the identification.

DNA data

DNA from five individuals (three from Tacoronte and two from Las Américas) was extracted using QIAGEN DNeasy Blood and Tissue Kit. Cytochrome oxidase II was amplified using TL-J-3037(TED)/TK-N-3785 (EVA) primers (Simon et al., 1994).

Sequences obtained were MAFFT aligned with reference sequences of the genus *Reticulitermes* from GenBank, using the program Geneious 8.0.5. Median-joining networks (Bandelt, Forster, & Röhl, 1999) were calculated with PopART 1.7, keeping parameter $e = 0$, starting with minimum spanning trees combined within a single network, and then adding median vectors (consensus sequences) to reduce tree length.

Results

A 649 bp fragment was obtained, which was 99.38% identical to the sequence JQ280737 belonging to a *R. flavipes* specimen from New Orleans (USA), thus confirming the identification. All specimens were 100% genetically identical between each other (MH794537-MH794541). The sequences from Tenerife constituted a sister clade of another, which included sequences from both their place of origin and from some countries where it was previously introduced (Fig. 1).

This invasive species has been detected in an urbanised area in the northeast within Tacoronte municipality (Fig. 2A), as well as in a public garden in a shopping centre in Las Américas (Arona municipality), in the southwest of the island (Fig. 2B). In these areas, it was found in structural wood inside houses, as well as in other infrastructures such as telephone poles and public gardens. Moreover, it has also been detected in living ornamental trees (*Acacia* sp., *Delonix regia*, *Euphorbia pulcherrima*, *Ficus elastica*, *Schefflera actinophylla* and *Washingtonia filifera*), fruit trees (*Passiflora edulis*, *Prunus persica* and *Vitis vinifera*) and native plant species (*Euphorbia lamarckii* and *Dracaena draco*, the Tenerife natural symbol).

The species was found in Tacoronte in a newly built residential estate near the coast (2010) and has later spread. After these termite infestations were treated, in 2015 and 2016 it was again detected at the edge of the same area. In 2017 a new population was discovered in other nearby houses. Finally, in 2018 more colonies appeared along a road

towards the northeast. It is thought that the species has been present on Tenerife since 2007. However, we were not able to determine its precise establishment point and thus only data from 2010 to 2018 are given.

Discussion

The genetic results confirmed the identity of the introduced termite populations as *Reticulitermes flavipes*. However, the origin of this introduction could not be identified, as the Tenerife sequences were related to a clade composed of sequences from multiple origins within its native and introduced distributional range.

To date, the ‘eastern subterranean termite’ has been detected in two relatively small areas on Tenerife. Despite this, the species has already caused notable damage to buildings and trees and generated serious economic costs, as happens in most places where this species is active (Ghesini et al., 2011).

Termite infestation has a devastating impact on historical architectural heritage; this has been studied in some specific cases (Gambetta, Zaffagnini, & De Capua, 2000; Su, Hillis-Starr, Ban, & Scheffrahn, 2003; Mello et al., 2014).. Its expansion on the Canary Islands may cause material and economic damage and irreversible harm to such heritage. It is particularly necessary to prevent the arrival of *R. flavipes* to areas of Tenerife with historic buildings, such as those in Tacoronte and La Laguna. Furthermore, its detection in living trees expands the possibility of damage to crops, since there is evidence of citrus infestation in Florida (Stansly, Su, & Conner, 2001). Moreover, the presence of these termites in thermophilous native species could be the first step in its establishment in natural ecosystems, as occurred in France, where introduced *R. flavipes* populations have been found in a natural pine forest (Dronnet, Chapuisat, Vargo, Lohou, & Bagnères, 2005).

Reticulitermes flavipes colonies were found closely related to residential areas and roads, a pattern also observed by Baudouin, Bech, Bagnères, & Dedeine (2018) in Paris. Its spread seems to be rapid, since the spread in its distribution in recent years has been noteworthy. It could be even faster taking into account that some infested places are greenhouses and plant nurseries. These areas maintain stable high temperatures and soil moisture throughout the year, thus favouring its establishment and dispersion (Cao & Su, 2016; Su & Puche, 2013).

The presence of *R. flavipes* in two distinct places, separated by about 60 km, leads us to expect that this species may be more widespread on the island, and may have been unintentionally dispersed by human activities such as the sale of ornamental and fruit trees. Therefore, we recommend preventing *R. flavipes* dispersal, in addition to eradicating it as soon as possible from the places where it has been detected, in order to minimise the damage and economic costs.

Author contributions

David Hernández-Teixidor, Daniel Suárez, Javier García and David Mora surveyed the infested areas and collected data. Daniel Suárez and David Hernández-Teixidor did the molecular analysis. David Hernández-Teixidor, Daniel Suárez and Javier García contributed to the writing.

References

Aber, A. & Fontes, L. R. (1993). *Reticulitermes lucifugus* (Isoptera, Rhinotermitidae), a pest of wooden structures, is introduced into the South American continent. *Sociobiology*, 21, 335-339.

176 Austin, J. W., Szalanski, A. L., Myles, T. G., Borges, P. A. V., Nunes, L. & Scheffrahn,
177 R. H. (2012). First record of *Reticulitermes flavipes* (Isoptera: Rhinotermitidae)
178 from Terceira island (Azores, Portugal). *Florida Entomologist*, 95, 196–198.
179 <https://doi.org/10.1653/024.095.0131>.

180 Austin, J. W., Szalanski, A. L., Scheffrahn, R. H., Messenger, M. T., Dronnet, S. &
181 Bagnères, A. G. (2005). Genetic evidence for the synonymy of two
182 *Reticulitermes* species: *Reticulitermes flavipes* and *Reticulitermes santonensis*.
183 *Annals of the Entomological Society of America*, 98(3), 395-401.

184 Becker, G. (1970). *Reticulitermes* in mittel und west Europa. *Zeitschrift für Angewandte*
185 *Entomologie*. 65: 268-278.

186 Behr, E. A., Behr, C. T. & Wilson, L. F. (1972). Influence of wood hardness on feeding
187 by the eastern subterranean termite, *Reticulitermes flavipes* (Isoptera:
188 Rhinotermitidae). *Annals of the Entomological Society of America*, 65, 457–460.
189 <https://doi.org/10.1093/aesa/65.2.457>.

190 Bandelt, H.J., Forster, P. & Röhl, A. (1999) Median-joining networks for inferring
191 intraspecific phylogenies. *Molecular Biology and Evolution*, 16, 37–48.

192 Baudouin, G., Bech, N., Bagnères, A. G. & Dedeine, F. (2018). Spatial and genetic
193 distribution of a north American termite, *Reticulitermes flavipes*, across the
194 landscape of Paris. *Urban Ecosystems*, 21, 751 – 764.
195 <https://doi.org/10.1007/s11252-018-0747-9>.

196 Cao, R. & Su, N. Y. (2016). Temperature preferences of four subterranean termite
197 species (Isoptera: Rhinotermitidae) and temperature-dependent survivorship and
198 wood-consumption rate. *Annals of the Entomological Society of America*, 109,
199 64–71. <https://doi.org/10.1093/aesa/sav095>.

200 Dronnet, S., Chapuisat, M., Vargo, E. L., Lohou, C., & Bagnères, A. G. (2005). Genetic
 201 analysis of the breeding system of an invasive subterranean termite,
 202 *Reticulitermes santonensis*, in urban and natural habitats. *Molecular Ecology*,
 203 *14*, 1311-1320. <https://doi.org/10.1111/j.1365-294X.2005.02508.x>

204 Evans, T. A., Forschler, B. T. & Grace, K. J. (2013). Biology of invasive termites: A
 205 worldwide review. *Annual Review of Entomology*, *58*, 455–474.
 206 <https://doi.org/10.1146/annurev-ento-120811-153554>.

207 Ferreira, M. T., Borges, P. A. V., Nunes, L., Myles, T. G., Guerreiro, O. & Scheffrahn,
 208 R. H. (2013). Termites (Isoptera) in the Azores: an overview of the four invasive
 209 species currently present in the archipelago. *Arquipelago. Life and Marine*
 210 *Sciences*, *30*, 39–55. ISSN 0873-4704.

211 Forschler, B. T. & Jenkins, T. M. (2000). Subterranean termites in the urban landscape:
 212 Understanding their social structure is the key to successfully implementing
 213 population management using bait technology. *Urban Ecosystems*, *4*, 231–251.

214 Gambetta, A., Zaffagnini, V., & De Capua, E. (2000). Use of hexaflumuron baits
 215 against subterranean termites for protection of historical and artistic structures:
 216 experiment carried out in selected test areas at the church of Santa Maria della
 217 Sanità in Naples. *Journal of Cultural Heritage*, *1*(3), 207-216.

218 Ghesini, S., Pilon, N. & Marini, M. (2011). A new finding of *Reticulitermes flavipes* in
 219 northern Italy. *Bulletin of Insectology*, *64*, 83–85. ISSN 1721-8861.

220 Heisterberg, W. (1958). Bemerkungen zum Thema: Termitengefahr in Österreich.
 221 *Holzforschung und Holzverwertung*, *10*, 66-67.

222 Khan, M. A. & Ahmad, W. (2018). Termites: An Overview. In M.A. Khan, W. &
 223 Ahmad (Eds.), *Termites and Sustainable Management* (pp. 1–25). Cham,
 224 Switzerland: Springer.

225 Krishna, K., Grimaldi, D. A., Krishna, V. & Engel, M. S. (2013). Treatise on the
 226 Isoptera of the World. Volume 1: Introduction. *Bulletin of the American Museum*
 227 *of Natural History*, 377, 1–200. <https://doi.org/10.1206/377.1>.

228 Mello, A. P., Costa, B. G., Silva, A. C., Silva, A. M. B., & Bezerra-Gusmão, M. A.
 229 (2014). Termites in historical buildings and residences in the semiarid region of
 230 Brazil. *Sociobiology*, 61(3), 318–323.

231 Perdereau, E., Dedeine, F., Christidès, J. P., Dupont, S. & Bagnères, A. G. (2011).
 232 Competition between invasive and indigenous species: an insular case study of
 233 subterranean termites. *Biological Invasions*, 13, 1457–1470.
 234 <https://doi.org/10.1007/s10530-010-9906-5>.

235 Perdereau, E., Bagnères, A. G., Vargo, E. L., Baudouin, G., Xu, Y., Labadie, P.,
 236 Dupont, S. & Dedeine, F. (2015). Relationship between invasion success and
 237 colony breeding structure in a subterranean termite. *Molecular Ecology*, 24,
 238 2125–2142. <https://doi.org/10.1111/mec.13094>.

239 Reaser, J. K., Meyerson, L. A., Cronk, Q., De Poorter, M. A. J., Eldrege, L. G., Green,
 240 E., Kairo, M., Latasi, P., Mack, R. N., Mauremootoo, J., O'Dowd, D., Orapa, W.,
 241 Sastroutomo, S., Saunders, A., Shine, C., Thrainsson, S. & Vaiutu, L. (2007).
 242 Ecological and socioeconomic impacts of invasive alien species in island
 243 ecosystems. *Environmental Conservation*, 34, 98–111.
 244 <https://doi.org/10.1017/S0376892907003815>.

245 Ripa, R. & Castro, L. (2000). Presencia de la termita subterranea *Reticulitermes*
 246 *santonensis* de Feytaud (Isoptera: Rhinotermitidae) en la comuna de Quillota. In
 247 *XXII Chilean Congress of Entomology*, Valdivia.

248 Rust, M. K., & Su, N. Y. (2012). Managing social insects of urban importance. *Annual*
 249 *Review of Entomology*, 57, 355–375. [https://doi.org/10.1146/annurev-ento-](https://doi.org/10.1146/annurev-ento-120710-100634)
 250 [120710-100634](https://doi.org/10.1146/annurev-ento-120710-100634).
 251 Scaduto, D. A., Garner, S. R., Leach, E. L. & Thompson, G. J. (2012). Genetic evidence
 252 for multiple invasions of the Eastern subterranean termite into Canada.
 253 *Environmental entomology*, 41(6), 1680-1686.
 254 Shelton, T. G., Hu, X. P., Appel, A. G. & Wagner, T. L. (2006). Flight speed of tethered
 255 *Reticulitermes flavipes* (Kollar) (Isoptera: Rhinotermitidae) alates. *Journal of*
 256 *Insect Behavior*, 19, 115–128. <https://doi.org/10.1007/s10905-005-9012-1>.
 257 Simon, C., Frati, F., Beckenbach, A.T., Crespi, B., Liu, H. & Flook, P. (1994)
 258 Evolution, weighting, and phylogenetic utility of mitochondrial gene sequences
 259 and a compilation of conserved polymerase chain reaction primers. *Annals of the*
 260 *Entomological Society of America*, 87, 651–701.
 261 <https://doi.org/10.1093/aesa/87.6.651>.
 262 Stansly, P. A., Su, N. Y., & Conner, J. M. (2001). Management of subterranean
 263 termites, *Reticulitermes* spp. (Isoptera: Rhinotermitidae) in a citrus orchard with
 264 hexaflumuron bait. *Crop Protection*, 20, 199-206.
 265 [https://doi.org/10.1016/S0261-2194\(00\)00127-7](https://doi.org/10.1016/S0261-2194(00)00127-7).
 266 Su, N. Y., Hillis-Starr, Z., Ban, P. M., & Scheffrahn, R. H. (2003). Protecting historic
 267 properties from subterranean termites: a case study with Fort Christiansvaern,
 268 Christiansted National Historic Site, United States Virgin Islands. *American*
 269 *Entomologist*, 49(1), 20-32.
 270 Su, N. Y., & Puche, H. (2003). Tunneling activity of subterranean termites (Isoptera:
 271 Rhinotermitidae) in sand with moisture gradients. *Journal of Economic*
 272 *Entomology*, 96, 88–93. <https://doi.org/10.1603/0022-0493-96.1.88>.

Suppo, C., Robinet, C., Perderau, E., Andrieu, D. & Bagnères, A. G. (2018). Potential spread of the invasive North American termite, *Reticulitermes flavipes*, and the impact of climate warming. *Biological Invasions*, 20, 905–922. <https://doi.org/10.1007/s10530-017-1581-3>.

Vargo, E. L. & Hussenader, C. (2009). Biology of subterranean termites: insights from molecular studies of *Reticulitermes* and *Coptotermes*. *Annual Review of Entomology*, 54, 379–403. 10.1146/annurev.ento.54.110807.090443.

Whittaker, R. J. & Fernández-Palacios, J. M. (2007). *Island biogeography: ecology, evolution, and conservation*. Oxford: University Press.

Figure legends

Figure 1:

Median-joining networks of *Reticulitermes flavipes* species based on the mitochondrial data set (*cox2*) from a sample of 46 individuals and 649 bp DNA sequences. Circle size is proportional to the number of samples within a given haplotype and lines between haplotypes represent mutational steps within alleles. Colours denote the geographical origin of the individuals used in the analysis. Reference Sequences codes correspond to GenBank accession numbers. *Reticulitermes labralis* was used as outgroup in the analysis.

Figure 2: Location of the sampling areas on the island of Tenerife (top left) and historical detection of *R. flavipes* (bottom left) in Tacoronte municipality (A, top right) and Las Américas (Arona municipality) (B, bottom right). Each colony is represented with circles of different colours according to the year it was first observed. A 150 m buffer area (see Baudouin et al., 2018) was applied to every colony detected, to represent the average foraging distance.