

SHORT COMMUNICATION

Bat droppings collection by ants in epigeal environments

J. Manuel Vidal-Cordero  | Jesús Nogueras  | Elena Tena 

Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas (CSIC), Sevilla, Spain

Correspondence

Jesús Nogueras, Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas (CSIC), Av. Américo Vespucio 26, 41092 Sevilla, Spain.
Email: nogueras@ebd.csic.es

Funding information

CILIFO_5_E; Consejo Superior de Investigaciones Científicas; FIREPOCTEP_6_E; SUMHAL, LIFEWATCH-2019-09-CSIC-4, POPE 2014-2020; Spanish Ministry for Science and Innovation; European Regional Development Fund; FEDER Funds

Associate Editor: Tali Reiner Brodetzki

Abstract

1. Ants can be found in insect communities associated with droppings, but most studies about this interaction have been carried out in subterranean environments, specifically in the study of the interaction between ants and bat guano.
2. In this report, we describe the first case of interaction between seven different ant species and the droppings of two bat species in epigeal environments. The study was performed in bat roosts monitored from March to October 2022 in the Doñana Biological Reserve of the Doñana National Park (Huelva, SW Spain). It was carried out via direct observations of droppings deposited on the ground surface or in tree-mounted dropping collectors below bat boxes.
3. We report a total of 37 interactions by seven different species of ants with droppings of two species of bat, the soprano pipistrelle (*Pipistrellus pygmaeus*) and the greater noctule (*Nyctalus lasiopterus*), in four different habitats (*Eucalyptus camaldulensis*, *Pinus pinea*, *Populus alba* and ground surface).
4. The generalist characters and the omnivorous diets of the ant species observed, in addition to the abundant availability of droppings during a period of food scarcity, suggest that droppings are transported as a food resource, with the consequent implications that this interaction may have on faecal degradation and nutrient cycling, as one of the supporting services provided by ants.

KEYWORDS

ant ecology, Chiroptera, ecological service, Formicidae, guano, invasive species

INTRODUCTION

Insect communities associated with droppings can be very diverse, from specialist to more generalist or predatory species that colonise faecal deposits during the different stages of their decomposition (Sánchez Piñero & Avila, 2004). Ants are among the generalist insects associated with excreta, especially in nutrient-poor ecosystems such as arid and semi-arid environments, where they can represent a substantial proportion of the total abundance of insects found in droppings (Sánchez Piñero & Avila, 2004).

In caves, guano deposits provided by cave-dwelling vertebrates, such as birds and bats, represent a very important source of nutrients (Kováč, 2018). Of the over 130 ant species found in caves, a minority

are troglobiont species that can feed on guano (Tinaut Ranera, 2023), whereas the vast majority are troglone species that make intermittent use of caves to hunt other invertebrates (Pape, 2016). Therefore, subterranean guano deposits do not influence the species richness of ants frequenting caves (Dáttilo et al., 2012; Dejean et al., 2015), but they do influence functional diversity of their communities (Dejean et al., 2015).

This ecological relationship between ants and bat guano, however, remains understudied in non-hypogean environments where bat droppings are present. These interactions have not even been recorded as natural history observations, except for Alcalde and Antón (2014), in which they observed the collection of droppings from a soprano pipistrelle (*Pipistrellus pygmaeus* Leach, 1825) colony

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2023 The Authors. *Ecological Entomology* published by John Wiley & Sons Ltd on behalf of Royal Entomological Society.

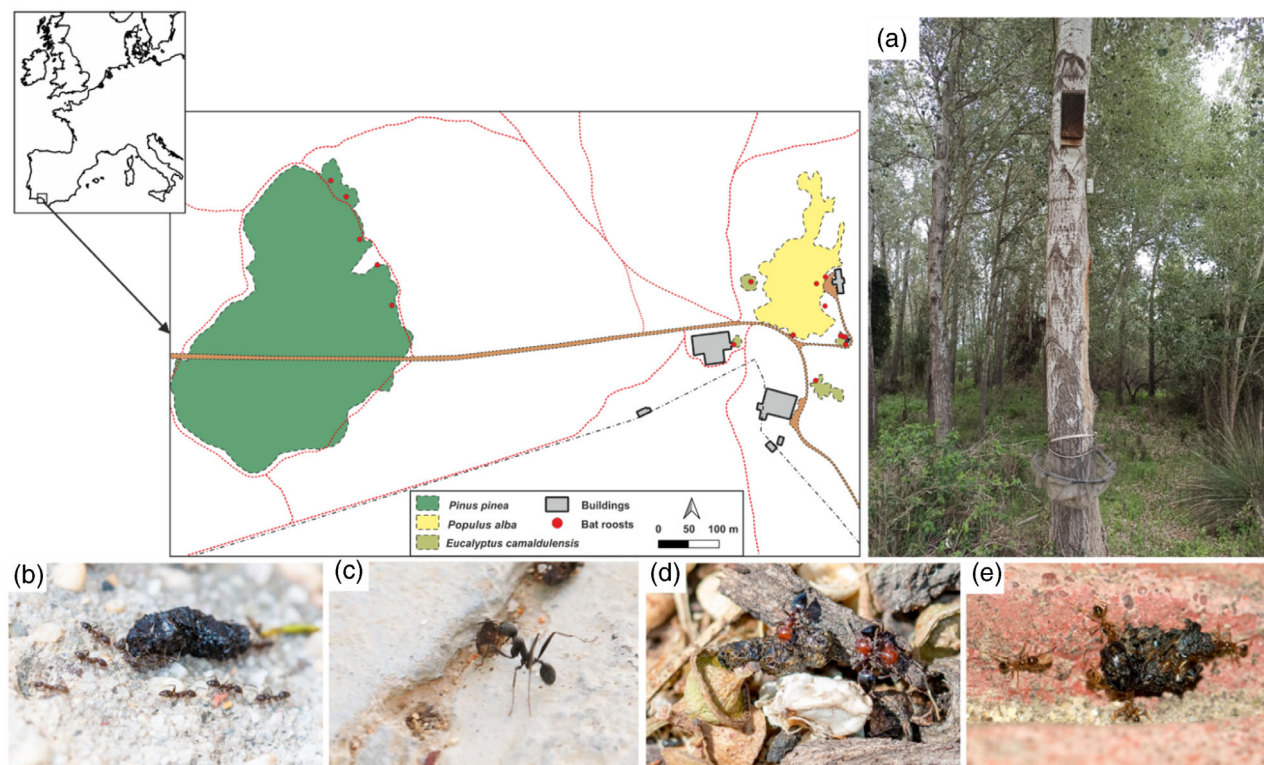


FIGURE 1 The study area located in southwestern Spain and photographs of a bat box with a dropping collector and four examples of different ant species observed interacting with bat droppings on the ground surface. (a) Bat box in *Populus alba* with droppings collector below, (b) *Linepithema humile* workers extracting *Nyctalus lasiopterus* droppings fragments, (c) *Aphaenogaster senilis* worker transporting *Pipistrellus pygmaeus* droppings, (d) *Crematogaster scutellaris* worker transporting *Nyctalus lasiopterus* droppings, (e) *Pheidole pallidula* workers extracting *Nyctalus lasiopterus* droppings fragments.

in a poplar tree (*Populus alba* L., 1753), in Navarra (northern Spain), by *Crematogaster scutellaris* (Olivier, 1792), erroneously identified as *Formica rufa* L., 1761. In this note, we present the first documented records of droppings collection from two bat species by seven different species of the forest ant community of the Doñana National Park (Huelva, southern Spain).

MATERIALS AND METHODS

The study was conducted in bat roosts located in the Doñana Biological Reserve of the Doñana National Park (EBD-CSIC; hereinafter referred to as the Reserve; 37°1'N, 6°33'W; Huelva, SW Spain; Figure 1), from March to October 2022, when bats are active and producing droppings. The Reserve contains a bat research infrastructure consisting of 28 bat boxes of two different models (handmade natural cork and 1FQ Schwegler woodcrete) with bottom access holes, from which the droppings fall into bespoke mesh dropping collectors located below each box (Figure 1a). The bat boxes are installed in scattered trees or forests composed of stone pine (*Pinus pinea*, 13 bat boxes), river red gum (*Eucalyptus camaldulensis*, 9 bat boxes) and white poplar (*P. alba*, 6 bat boxes; Figure 1a). Two bat species roost in these boxes; the soprano pipistrelle (*P. pygmaeus*) is the most abundant

species within the study area, with an approximate population of 5,000 individuals. It is a crevice and tree-dwelling species, which roosts in both bat boxes and buildings located within the Reserve. The greater noctule (*Nyctalus lasiopterus*) is a tree-dwelling species with fewer than a hundred individuals within the Reserve, only roosting inside bat boxes (Popa-Lisseanu & Ibáñez, 2007; Santos et al., 2016).

A total of 14 inspections were made of the 28 dropping collectors between sunrise and sunset. The day before the visit, the dropping collectors were emptied into a bag to remove the excess droppings, which had accumulated to date. From the following day onwards, each dropping collector was checked during a week and observed for 2 min to detect any ant-droppings interactions. For the purposes of this paper, we defined ant-droppings interactions as ants transporting droppings or parts of them with their mandibles or trying to extract part of the droppings (Figure 1b–e). For each interaction, the temperature of the trunk/ground surface was recorded using an infrared thermometer (PCE instruments PCE-777N) at a distance of half a metre. Five to ten ants were also collected using a wet brush and preserved in a microtube containing 70% ethanol for subsequent identification in the laboratory.

We also checked the ground surface for ant-droppings interactions below four known roosts of *P. pygmaeus* in built structures

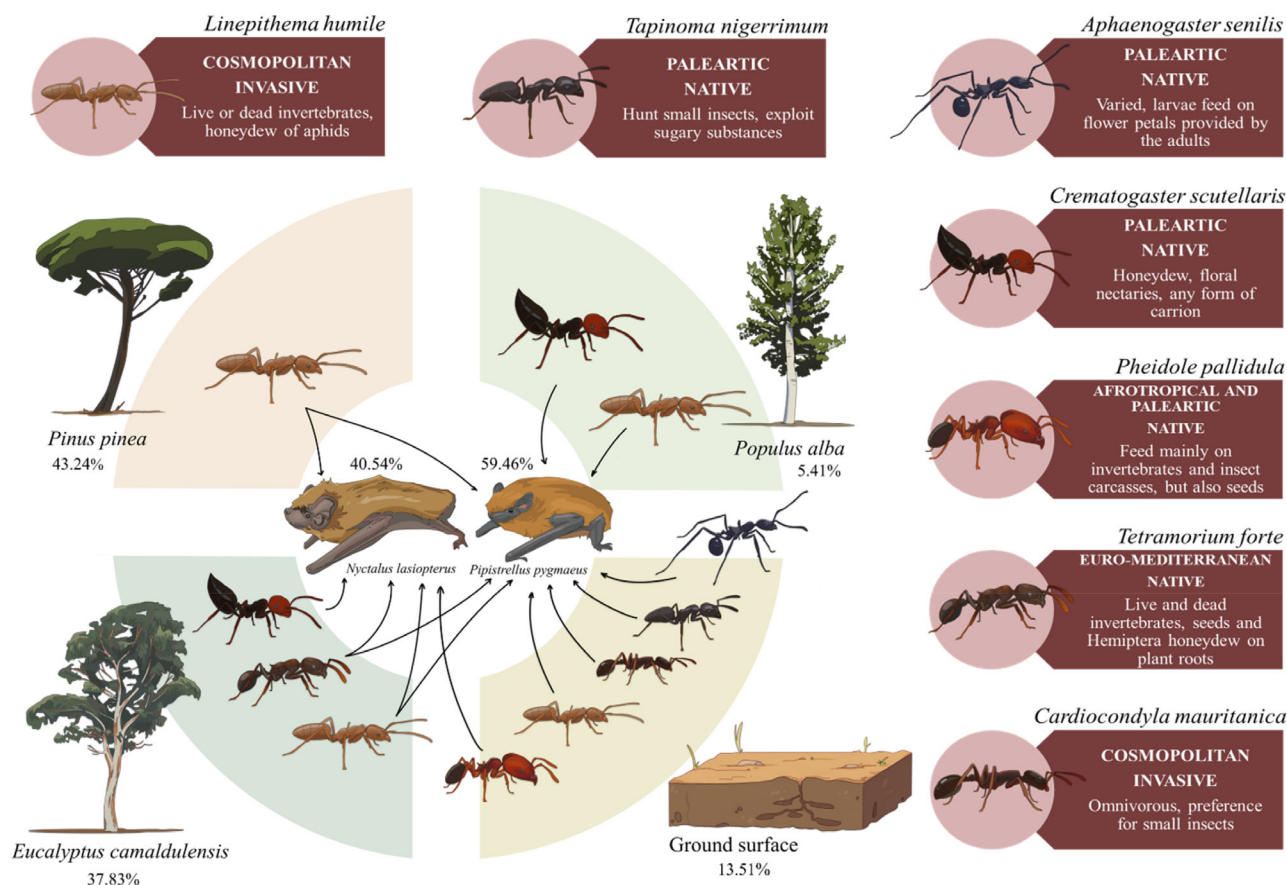


FIGURE 2 Interactions observed between ant species and bat droppings in the different habitats of our study area and information about the general distribution and diet of the different ant species (Lebas et al., 2017). The percentages calculated for the bat species and the different habitats are based on a total of 37 observations of bat-droppings interactions. The observation of *Pheidole pallidula* corresponds to the one found at the Zoobotanical Park of Jerez de la Frontera (Cádiz, Spain).

within the Reserve, and followed the same protocols when these interactions were observed. We added a further ant-droppings interaction on the ground surface at the Zoobotanical Park of Jerez de la Frontera (Cádiz, Spain), outside of the Doñana National Park, when two of the authors were processing greater noctules from a roost of 100–300 individuals (Popa-Lisseanu & Ibáñez, 2007; Santos et al., 2016).

RESULTS AND DISCUSSION

A total of 37 ant-droppings interactions were recorded for seven different ant species (Figure 2) at a mean surface temperature of 32.83°C, with a minimum of 23.5°C and a maximum of 48°C. Of the total number of observations ($n = 392$), 9.44% presented ant-droppings interactions; 59.46% were with the droppings of *P. pygmaeus* and 40.54% of *N. lasiopterus*. A total of 37.84% of the interactions occurred in dropping collectors located on river red gum (*E. camaldulensis*), 43.24% on stone pine (*P. pinea*), 5.41% on white poplar (*P. alba*) and 13.51% were interactions observed on the ground surface. The higher percentages of bat-droppings interactions on river

red gum and stone pine are due to the higher abundance of bat boxes placed on these two tree species (Figures 1 and 2).

On the other hand, 81.08% of ant-droppings interactions had the Argentine ant (*Linepithema humile*) as the focal species. The remaining percentage belonged to interactions of other ant species with droppings, which we only observed on one or two occasions (in the case of *C. scutellaris*) and mainly on the ground surface (Figure 2). Of the over 40 ant species previously recorded in the Reserve (Amor & Ortega, 2014), the Argentine ant (*L. humile*) is the only invasive species recorded to date. This species tends to dominate and displace the communities of native ants in those areas where it is present (Angulo et al., 2011; Carpintero, 2003). Moreover, *Cardiocondyla mauritanica* was found interacting with *P. pygmaeus* droppings on the ground surface and it is also considered an exotic species in Spain. Our observation is the first record of this ant species in the Doñana National and Natural Park and its presence constitutes a second invasive species for the area.

All the ant species observed have an omnivorous diet in common, consisting of a varied intake including live and dead invertebrates, carrion of different origins, seeds and sugary substances from floral nectaries or honeydew excreted by Hemiptera or other insects (Figure 2).

Their tendency towards one or another type of food may depend on the food requirements of the colony cycle of each ant species, but also on the availability of food in the environment (Caut et al., 2015). The droppings produced by the bat colonies roosting in the bat boxes in our study area are abundant during the peak ant activity season and can constitute a food resource for the different species mentioned, especially in times of food shortage. This is supported by studies carried out in nutrient-poor environments such as arid and semi-arid ecosystems like the one of the Reserve (Sánchez Piñero & Avila, 2004), where ants were dominant in faeces during the summer months (Sánchez Piñero & Avila, 2004). Also, the ability of some ant species (e.g., *Camponotus* spp.) to extract nutrients, like urea, from vertebrate waste may broaden their ecological niche in competitive and very nitrogen-limited environments (Petit et al., 2020).

Droppings from insectivorous bats are considered a very nutritive source due to its exceptionally high content of nitrogen, phosphate and potassium (Sakoui et al., 2020). Faeces primarily consist of high fatty acids and proteins (Lam et al., 2013), mainly comprising chitinised parts from insect exoskeletons. Even though most ant species consume food in a liquid state, Bouchebti et al. (2023) recently investigated the metabolism of ingested chitin by insectivorous social insect larvae. Consequently, it is not surprising that bat faeces in epigeal environments could be regarded as a nutritional source for ants.

The activity of insects living in association with droppings is crucial for faecal decomposition and incorporation of nutrients into the soil that can lead to improved primary productivity (Evans et al., 2019). The removal of droppings by ants and its incorporation into ant hills contributes towards enhancing nutrient cycling, one of the supporting services provided by ants (Del Toro et al., 2012). However, the present study is only based on observational data mainly associated with dropping collectors already installed in habitats whose ant community is affected by the presence of an invasive species. An in-depth study is required to understand the interactions of ant species with bat droppings deposited on the ground. We also urge the scientific community to explore how long ants take to remove droppings, what nutrients they extract from them, whether they have a preference in collecting droppings from one species of bat over another depending on the bats' differing trophic strategies and what effect the introduction of droppings into ant nests may have on the physico-chemical properties of soil and plant productivity. Thus, by examining the ecological implications of the interplay between ants and bat droppings in epigeal environments, we can further advance our understanding in this field.

AUTHOR CONTRIBUTIONS

J. Manuel Vidal-Cordero: Conceptualization; methodology; investigation; data curation; visualization; writing – original draft; writing – review and editing; resources; supervision. **Jesús Noguerras:** Methodology; data curation; investigation; supervision; visualization; funding acquisition; writing – review and editing; resources. **Elena Tena:** Conceptualization; methodology; investigation; data curation; supervision; resources; writing – review and editing; funding acquisition; visualization.

ACKNOWLEDGEMENTS

We are grateful to Sergio Ibarra Mellado for producing Figure 2, to Carlos Ibáñez for his support and encouraging comments, to Sonia Sánchez-Navarro for making this manuscript possible and to Tyson Lee Holmes for his revision of the English language. J. Manuel Vidal-Cordero was supported by the European Regional Development Fund Journal Pre-proof (Interreg V A Spain–Portugal program [POCTEP] through the CILIFO [Ref. 0753_CILIFO_5_E] and FIREPOCTEP [Ref. 0756_FIREPOCTEP_6_E]). Elena Tena was funded by the Spanish Ministry for Science and Innovation project through European Regional Development Fund (SUMHAL, LIFEWATCH-2019-09-CSIC-4, POPE 2014-2020). Logistic and technical support was provided by ICTS-RBD-CSIC, Ministry of Science and Innovation, and co-financed by FEDER Funds.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

ORCID

J. Manuel Vidal-Cordero  <https://orcid.org/0000-0003-2346-1195>

Jesús Noguerras  <https://orcid.org/0000-0002-5411-8173>

Elena Tena  <https://orcid.org/0000-0003-4406-5933>

REFERENCES

- Alcalde, J. & Antón, I. (2014) Recolección de guano de murciélagos de Cabrera (*Pipistrellus pygmaeus*) por hormigas rojas (*Formica rufa*). *Barbastella*, 7, 32–34.
- Amor, F. & Ortega, P. (2014) *Cataglyphis tartessica* sp.n., a new ant species (Hymenoptera: Formicidae) in south-western Spain. *Myrmecological News*, 19, 125–132.
- Angulo, E., Caut, S. & Cerdá, X. (2011) Scavenging in Mediterranean ecosystems: effect of the invasive Argentine ant. *Biological Invasions*, 13, 1183–1194.
- Bouchebti, S., Cohen, T.M., Bodner, L. & Levin, E. (2023) Chitin digestion in a eusocial insect: the digestive role of larvae in hornet colonies. *Entomologia Generalis*, 43, 491–494.
- Carpintero, S. (2003) Distribution of the invasive Argentine ant (*Linepithema humile*) in Doñana National Park (Spain) and displacement of native ant species. *Ecologia Mediterranea*, 29, 250.
- Caut, S., Barroso, Á., Cerdá, X., Amor, F. & Boulay, R.R. (2015) A year in an ant's life: opportunism and seasonal variation in the foraging ecology of *Aphaenogaster senilis*. *Biological Invasions*, 20, 19–27.
- Dáttilo, W., Vicente, R.E., Nunes, R.V. & Feitosa, R.M. (2012) Influence of cave size and presence of bat guano on ant visitation. *Sociobiology*, 2, 549–559.
- Dejean, A., Groc, S., Héroult, B., Rodríguez-Pérez, H., Touchard, A., Céréghino, R. et al. (2015) Bat aggregation mediates the functional structure of ant assemblages. *Comptes Rendus Biologies*, 338, 688–695.
- Del Toro, I., Ribbons, R.R. & Pelini, S. (2012) The little things that run the world revisited: a review of ant-mediated ecosystem services and disservices (Hymenoptera: Formicidae). *Myrmecological News*, 17, 133–146.
- Evans, K.S., Mamo, M., Wingeyer, A., Schacht, W.H., Eskridge, K.M., Bradshaw, J. et al. (2019) Soil fauna accelerate dung pat

- decomposition and nutrient cycling into grassland soil. *Rangeland Ecology & Management*, 72, 667–677.
- Kováč, Ľ. (2018) Caves as oligotrophic ecosystems. In: Moldovan, O., Kováč, Ľ., Halse, S. (eds) *Cave Ecology*. Ecological Studies vol. 235. Springer, Cham.
- Lam, M.M.Y., Martin-Creuzburg, D., Rothhaupt, K.O., Safi, K., Yohannes, E. & Salvarina, I. (2013) Tracking diet preferences of bats using stable isotope and fatty acid signatures of faeces. *PLoS One*, 8, e83452.
- Lebas, C., Galkowski, C., Blatrix, R. & Wegnez, P. (2017) *Guía de campo de las hormigas de Europa Occidental*. Barcelona: Ediciones Omega, p. 415.
- Pape, R.B. (2016) The importance of ants in cave ecology, with new records and behavioral observations of ants in Arizona caves. *International Journal of Speleology*, 45, 185–205.
- Petit, S., Stonor, M.B., Weyland, J.J., Gibbs, J. & Amato, B. (2020) Campo-notus ants mine sand for vertebrate urine to extract nitrogen. *Austral Ecology*, 45, 168–176.
- Popa-Lisseanu, A.G. & Ibáñez, C. (2007) Ecología espacial y trófica del nóctulo gigante (*Nyctalus lasiopterus*) en el Parque Nacional de Doñana y su entorno. In: *Proyectos de Investigación en Parques Nacionales: 2003–2006*. Madrid: Organismo Autónomo de Parques Nacionales, Ministerio de Medio Ambiente, pp. 261–279.
- Sakoui, S., Derdak, R., Addoum, B., Serrano-Delgado, A., Soukri, A. & El Khalfi, B. (2020) The life hidden inside caves: ecological and economic importance of bat guano. *International Journal of Ecology*, 2020, 1–7.
- Sánchez Piñero, F. & Avila, J.M. (2004) Dung-insect community composition in arid zones of south-eastern Spain. *Journal of Arid Environments*, 56, 303–327.
- Santos, J.D., Meyer, C.F., Ibáñez, C., Popa-Lisseanu, A.G. & Juste, J. (2016) Dispersal and group formation dynamics in a rare and endangered temperate forest bat (*Nyctalus lasiopterus*, Chiroptera: Vespertilionidae). *Ecology and Evolution*, 6, 8193–8204.
- Tinaut Ranera, A. (2023) Himenópteros, de avispa visitantes a hormigas permanentes. In: Sendra, A. (Ed.) *Habitantes de la oscuridad: Fauna Ibero-balear de las cuevas*. Zaragoza: Sociedad Entomológica Aragonesa, pp. 471–474.

How to cite this article: Vidal-Cordero, J.M., Nogueras, J. & Tena, E. (2024) Bat droppings collection by ants in epigeal environments. *Ecological Entomology*, 49(3), 445–449.
Available from: <https://doi.org/10.1111/een.13305>