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Free ride without raising a thumb: A citizen science project reveals the pattern of active ant hitchhiking on vehicles and its ecological implications

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Abstract

1. Species hitchhiking on human transportation objects such as vehicles can facilitate long-distance dispersal of organisms, allowing increased probabilities of successful biological invasions. In Taiwan, there have been observations of ants actively moving onto motor vehicles (defined as “ant hitchhiking” hereafter), yet no study has explored this phenomenon.

2. Here, we provide the first qualitative and quantitative report on ant hitchhiking behavior using citizen science data. From 2017 to 2023, 52 cases of ant hitchhiking on vehicles were reported, attributed to nine species. Seven out of the nine species were exotic/invasive. Arboreal or semi-arboreal ant species, particularly the invasive black cocoa ant (*Dolichoderus thoracicus*), accounted for over half of the reported cases. The parking duration of the vehicles on which the ants hitchhiked ranged from several hours to over a month (30 cases occurred within a day). Moreover, more cases were reported in the warmer seasons (spring and summer) than in the colder seasons (fall and winter).

3. To our knowledge, this study represents the first effort to profile active ant hitchhiking on vehicles. We encourage future studies to examine the abiotic and biotic factors that determine the success of hitchhiking events to better predict the spread of exotic ants and to develop effective management strategies for preventing their biological invasions.

Keywords

biological invasions, citizen science, exotic species, human-mediated dispersal, propagule pressure, transportation

Introduction

An ecological consequence of human transportation activity is the transfer of organisms to a new area via mobile equipment and related vehicles. Such "hitchhiking" can lead to long-distance dispersal of species beyond their natural ranges, potentially facilitating biological invasions (Auffret et al. 2014, Gippet et al. 2019). Numerous terrestrial animals and plants have been documented to hitchhike on vehicles. For example, plant seeds attached to cars and tire surface can be dispersed over long distances (Ansong and Pickering 2013); in some cases, the seeds can remain attached to vehicles for hundreds kilometers (Taylor et al. 2012). Insects of various life stages have also been recognized to be frequent hitchhikers on vehicles. For instance, the spongy moth (*Lymantria dispar*) lays eggs on the surface of shipping containers and trucks, and the eggs later arrive at the destinations as larvae (Gray 2017). Dispersal range of flying insects can be boosted via hitchhiking on vehicles: the tiger mosquito (*Aedes albopictus*) can travel in cars and move across provinces in Spain (Eritja et al. 2017).

Invasive ants have been reported to disperse via human cultural and commercial activities (Bertelsmeier et al. 2017). A well-established body of literature has demonstrated that the rapid range expansion of these ants is attributed to the transportation of ant-infested agricultural, horticultural, and construction materials (Jetter et al. 2002, Vogt and Kozlovac 2006). While the focus has been concentrated on ants inadvertently transported by infested agricultural and construction vehicles, reports on ants actively hitchhiking on vehicles—ants take the initiative to get onto

the vehicles, rather than being inadvertently brought by humans along with soil or timber—are lacking. Additionally, information about these incidents, such as seasonality or common hitchhiking ant species, is not available. Filling this knowledge gap would help develop effective management strategies to mitigate ant invasions resulting from hitchhiking.

To better understand this phenomenon, we collected active ant hitchhiking cases in Taiwan via a citizen science project and characterized the spatial and temporal patterns of ant hitchhiking incidences. Potential ecological implications will be discussed.

Materials and Methods

The data collection consisted of two phases. In the first phase (2017–2022), cases of ant hitchhiking on vehicles were gathered from Facebook where general public shares cases involving their own vehicles infested with ants of different castes (e.g., worker and queen) or life stages (e.g., brood). Each contributor provided the parking date and location of the vehicles, parking duration (from the time when the vehicle was parked to the time when the ant hitchhiking was observed), vehicle type (car or scooter), intended destination (which was used to infer how far the hitchhiking ants could travel if it managed to arrive with the vehicle), weather conditions, surrounding environment (e.g., whether there was any tree nearby), and a photo of the ants for species identification. In the second phase of this study (2023), a dedicated Facebook group (https://www.facebook.com/groups/577051257470900) was established to systematically collect the same metadata regarding each ant hitchhiking incidence. The data from the two phases were combined as a single dataset for subsequent analysis.

We categorized ant species into “arboreal”, “semi-arboreal”, or “ground-dwelling” functional groups based on their nesting sites and foraging habits (the definition of semi-arboreal ant is based on Yanoviak et al. 2011). The difference in the number of reported cases among the four seasons over the study period was analyzed via the Pearson's chi-square test. We also estimated the sampling completeness of our data using the R package “iNext” (Hsieh et al. 2016). All recorded cases and the metadata were provided in the Supplementary Data.

Results

We documented 52 cases of active ant hitchhiking on cars (*n* = 44) and scooters (*n* = 8) between 2017 and 2023, the majority of which were reported from central and northern Taiwan (Fig. 1a). From the photos provided, at least three cases were found to have queen(s) and eight cases with brood. Nine species, two native and seven exotic/invasive, were recorded and most of them were arboreal or semi-arboreal ants (Table S1). One species in particular, the black cocoa ant (*Dolichoderus thoracicus*), constituted approximately 60% of the reported cases (*n* = 31). While the parking duration of the vehicles on which the ants hitchhiked ranged from a few hours to over a month, over half of the hitchhiking incidences (*n* = 30) occurred within a day. The average distance between parking location and intended destination was around 60 km for 17 cases where the information of the intended destinations was available. Thirteen cases had a distance larger than 30 km (Fig. S1). (Note that these distance estimates represented the “potential” but not necessarily the “actual” ant movements. See Fig. S1 for more explanations.) The number of reported cases differed significantly among seasons ($\chi^2 = 25.69$, $df = 3$, $P < 0.001$) and was higher in the warmer seasons (spring and summer) than in the

colder seasons (fall and winter) (Fig. S2). The estimated sampling completeness of the data was 0.94 (95% CI: 0.89–0.99) (Fig. S3).

Discussion

This study provides the first qualitative and quantitative analysis of active ant hitchhiking behavior using citizen science data. Our analysis reveals that exotic/invasive ants were the major "hitchhikers" as they were over-represented in our records. Exotic ants often achieve high local population densities in human-mediated environments (Holway et al. 2002), which may have contributed to the higher frequency of exotic/invasive ants hitchhiking on vehicles compared to native ants. One major consequence of ant hitchhiking on vehicles is the accelerated spread of exotic/invasive ants. The distance between parking location and intended destination could be up to a few hundred kilometers (Fig. S1), largely exceeding the natural movements achievable through dispersal. Hitchhiking events could take place within several hours after parking, during which workers often carried brood along with queen(s) and moved together to the vehicles. This suggests that ant hitchhiking is not merely foraging behavior but appears to be a colonization attempt, potentially driven by high population pressure and the availability of preferred nesting spots offered by vehicles such as pre-existing physical space and crevices. Indeed, the exotic black cocoa ant (*D. thoracicus*), the most common hitchhiking species in our dataset, exhibits notably high local densities in central Taiwan and is frequently observed to move their nests from tree trunks to nearby pre-existing artificial structures with crevices (Hsu et al. 2022).

Our analysis identified at least three factors that are critical for a successful ant hitchhiking event (Fig. 2). First, ants need to encounter a vehicle, which largely

depends on their searching/exploratory behavior. More hitchhiking cases were reported in spring and summer compared to fall and winter (Fig. S2), consistent with ants generally foraging more actively under warmer conditions (Parr and Bishop 2022). Moreover, interactions between human behavior and ant habitats may lead to a higher probability of ants encountering vehicles. For example, arboreal ants typically exhibit frequent foraging activities and territorial patrolling around their nesting trees because of resource limitations in the canopies (particularly nitrogen availability) (Hashimoto et al. 2010). As vehicle operators often prefer parking sites with tree cover (especially during the warmer seasons), arboreal ants' encounter with vehicles can be largely increased. In fact, a large portion of our records involved the vehicles' surface coming into contact with the leaves and twigs of nearby trees, which serve as a physical pathway for ants to move onto the vehicles.

Second, ants need to climb or hold onto the vehicle after locating it. The metallic paint on vehicle surface is slippery and may potentially select for species with good climbing/gripping abilities. The climbing and moving performance of ants is determined by the morphological characteristics of leg segments (Beutel et al. 2020). Arboreal ants have hooked pretarsal claws, well-developed adhesive pads, and fine tarsal hairs, allowing them to walk on smooth vertical substrates. Ground-dwelling ants, on the contrary, are less capable of moving on smooth surface such as vehicle paint because of their straight pretarsal claws and the lack of adhesive pads and tarsal hairs (Orivel et al. 2001).

Third, the temperature on the surface and in the interior of the vehicle can increase dramatically when exposed to sunlight, especially in the summer, indicating the thermal tolerance of hitchhiking species may play an important role in determining their colonization success (Nixon et al. 2019). Arboreal ants are

generally more heat- and drought-tolerant than ground-dwelling ants are (Hood and Tschinkel 1990, Leahy et al. 2022), which could potentially translate into a higher probability of successful establishment at the destination due to better survival chance with high temperatures on or in the vehicle.

To our knowledge, this is the first report profiling active ant hitchhiking on vehicles via citizen science efforts, highlighting the importance of establishing a predictive framework for forecasting future hitchhikers based on behavioral, morphological, physiological, and ecological traits of ant species. Such a framework will help facilitate the development of effective management strategies for mitigating ant invasions via active hitchhiking on vehicles.

References

Ansong, M., and C. Pickering. 2013. Are weeds hitchhiking a ride on your car? A systematic review of seed dispersal on cars. PLoS ONE **8**:e80275.

Auffret, A. G., J. Berg, and S. A. Cousins. 2014. The geography of human-mediated dispersal. Diversity and Distributions **20**:1450-1456.

Bertelsmeier, C., S. Ollier, A. Liebhold, and L. Keller. 2017. Recent human history governs global ant invasion dynamics. Nature Ecology and Evolution **1**:0184.

Beutel, R. G., A. Richter, R. A. Keller, F. Hita Garcia, Y. Matsumura, E. P. Economo, and S. N. Gorb. 2020. Distal leg structures of the *Aculeata* (Hymenoptera): a comparative evolutionary study of *Sceliphron* (Sphecidae) and *Formica* (Formicidae). Journal of Morphology **281**:737-753.

Eritja, R., J. R. Palmer, D. Roiz, I. Sanpera-Calbet, and F. Bartumeus. 2017. Direct evidence of adult Aedes albopictus dispersal by car. Scientific Reports **7**:14399.

Gippet, J. M., A. M. Liebhold, G. Fenn-Moltu, and C. Bertelsmeier. 2019. Human-mediated dispersal in insects. Current Opinion in Insect Science **35**:96-102.

Gray, D. R. 2017. Risk analysis of the invasion pathway of the Asian gypsy moth: a known forest invader. Biological Invasions **19**:3259-3272.

Hashimoto, Y., Y. Morimoto, E. S. Widodo, M. Mohamed, and J. R. Fellowes. 2010. Vertical habitat use and foraging activities of arboreal and ground ants (Hymenoptera: Formicidae) in a Bornean tropical rainforest. Sociobiology **56**:435.

Holway, D. A., L. Lach, A. V. Suarez, N. D. Tsutsui, and T. J. Case. 2002. The causes and consequences of ant invasions. Annual Review of Ecology and Systematics **33**:181-233.

Hood, W. G., and W. R. Tschinkel. 1990. Desiccation resistance in arboreal and terrestrial ants. Physiological Entomology **15**:23-35.

Hsieh, T., K. Ma, and A. Chao. 2016. iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods in Ecology and Evolution **7**:1451-1456.

Hsu, F.-C., S.-P. Tseng, P.-W. Hsu, C.-W. Lu, C.-C. S. Yang, and C.-C. Lin. 2022. Introduction of a non-native lineage is linked to the recent black cocoa ant, *Dolichoderus thoracicus* (Smith, 1860), outbreaks in Taiwan. Taiwania **67**:271-279.

Jetter, K., J. Hamilton, and J. Klotz. 2002. Eradication costs calculated: Red imported fire ants threaten agriculture, wildlife and homes. California Agriculture **56**:26-34.

Leahy, L., B. R. Scheffers, S. E. Williams, and A. N. Andersen. 2022. Arboreality drives heat tolerance while elevation drives cold tolerance in tropical rainforest ants. Ecology **103**:e03549.

Nixon, L. J., A. Tabb, W. R. Morrison, K. B. Rice, E. G. Brockerhoff, T. C. Leskey, C. van Koten, S. Goldson, and M. Rostás. 2019. Volatile release, mobility, and mortality of diapausing *Halyomorpha halys* during simulated shipping movements and temperature changes. Journal of Pest Science **92**:633-641.

Orivel, J., M. Malherbe, and A. Dejean. 2001. Relationships between pretarsus morphology and arboreal life in ponerine ants of the genus *Pachycondyla* (Formicidae: Ponerinae). Annals of the Entomological Society of America **94**:449-456.

Parr, C. L., and T. R. Bishop. 2022. The response of ants to climate change. Global Change Biology **28**:3188-3205.

Taylor, K., T. Brummer, M. L. Taper, A. Wing, and L. J. Rew. 2012. Human-mediated long-distance dispersal: an empirical evaluation of seed dispersal by vehicles. Diversity and Distributions **18**:942-951.

Vogt, J. T., and J. P. Kozlovac. 2006. Safety considerations for handling imported fire ants (*Solenopsis* spp.) in the laboratory and field. Applied Biosafety **11**:88-97.

Yanoviak, S. P., Y. Munk, and R. Dudley. 2011. Evolution and ecology of directed aerial descent in arboreal ants. Integrative and Comparative Biology **51**:944-956.

Figures

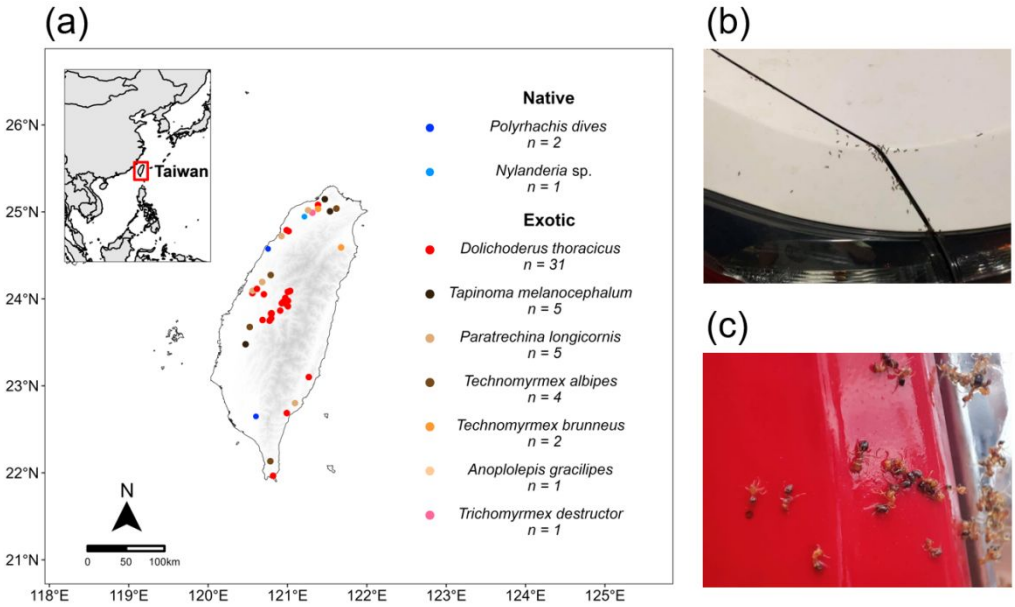

Figure 1. (a) Distribution and species of the ant hitchhiking cases; (b–c) example photos of ant hitchhiking on vehicles.

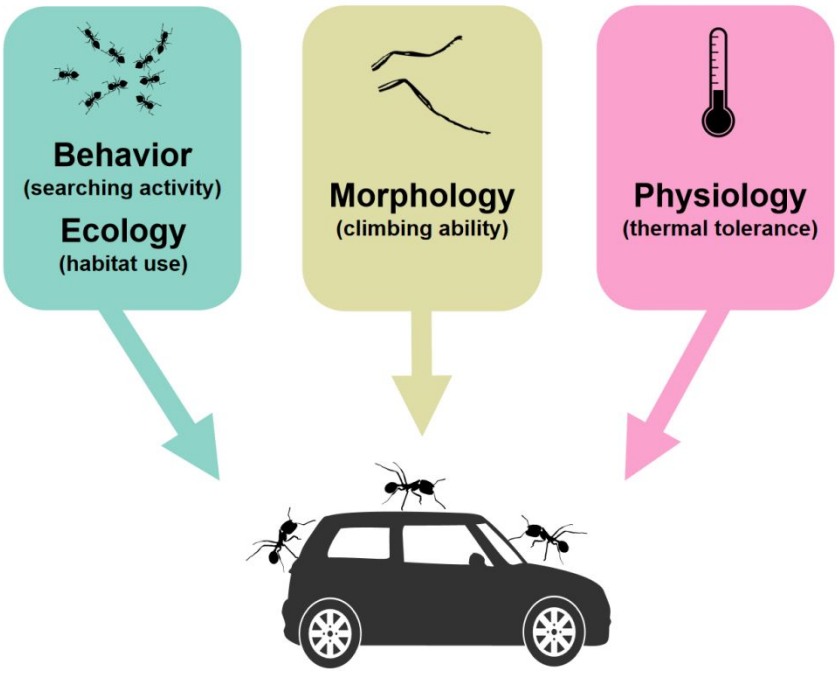

Figure 2. Potential factors determining a successful ant hitchhiking event. See *Discussion* for more details.

Supplementary Information

Table S1. The status, habitat association, and number of hitchhiking cases of the recorded ant species in this study

Species	Status	Habitat association	Number of cases
Polyrhachis dives	Native	Arboreal	2
Nylanderia sp.	Native	Ground-dwelling	1
Dolichoderus thoracicus	Exotic*	Arboreal	31
Tapinoma melanocephalum	Exotic	Semi-arboreal	5
Paratrechina longicornis	Exotic	Semi-arboreal	5
Technomyrmex albipes	Exotic	Arboreal	4
Technomyrmex brunneus	Exotic	Arboreal	2
Anoplolepis gracilipes	Exotic	Semi-arboreal	1
Trichomyrmex destructor	Exotic	Semi-arboreal	1

***** *Dolichoderus thoracicus* in central Taiwan has been demonstrated to a non-native lineage resulting from recent invasion (Hsu et al., 2022).

Reference: Hsu, F.-C., S.-P. Tseng, P.-W. Hsu, C.-W. Lu, C.-C. S. Yang, and C.-C. Lin. 2022. Introduction of a non-native lineage is linked to the recent black cocoa ant, Dolichoderus thoracicus (Smith, 1860), outbreaks in Taiwan. Taiwania 67:271-279.

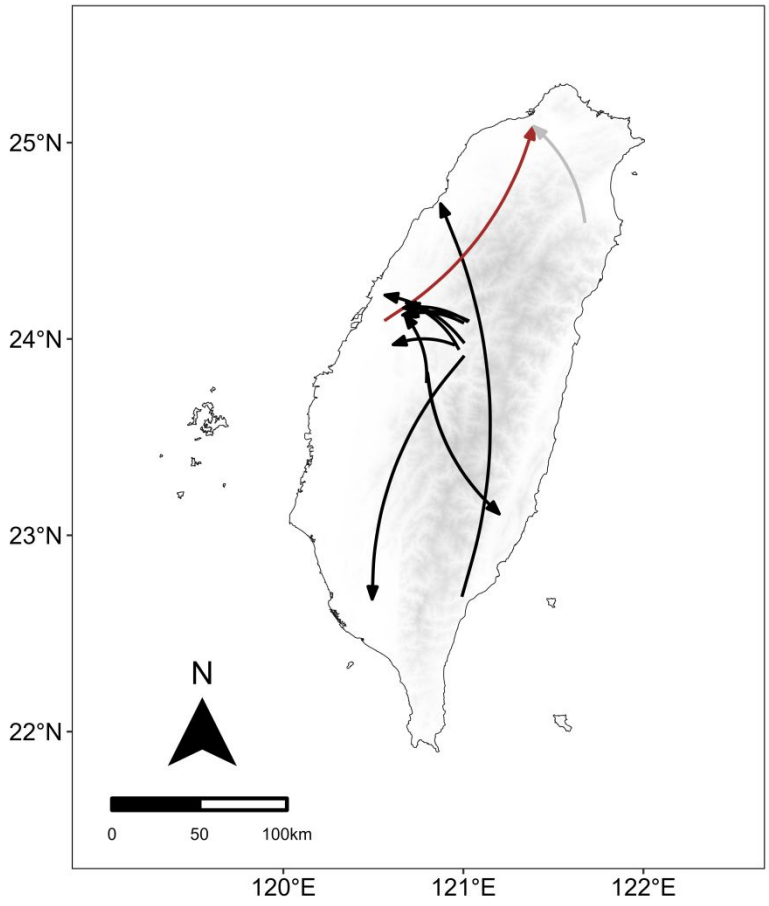

Figure S1. The movements of ant-colonized vehicles from the parking locations (arrow end) to the intended destinations (arrowhead) for 13 hitchhiking cases where the distance was larger than 30 km (black: *Dolichoderus thoracicus*; brown: *Tapinoma melanocephalum*; gray: *Technomyrmex brunneus*). Note that in many cases, the vehicle owners would attempt to remove the ants before driving. Therefore, these distance estimates represented the “potential” but not necessarily the “actual” ant movements.

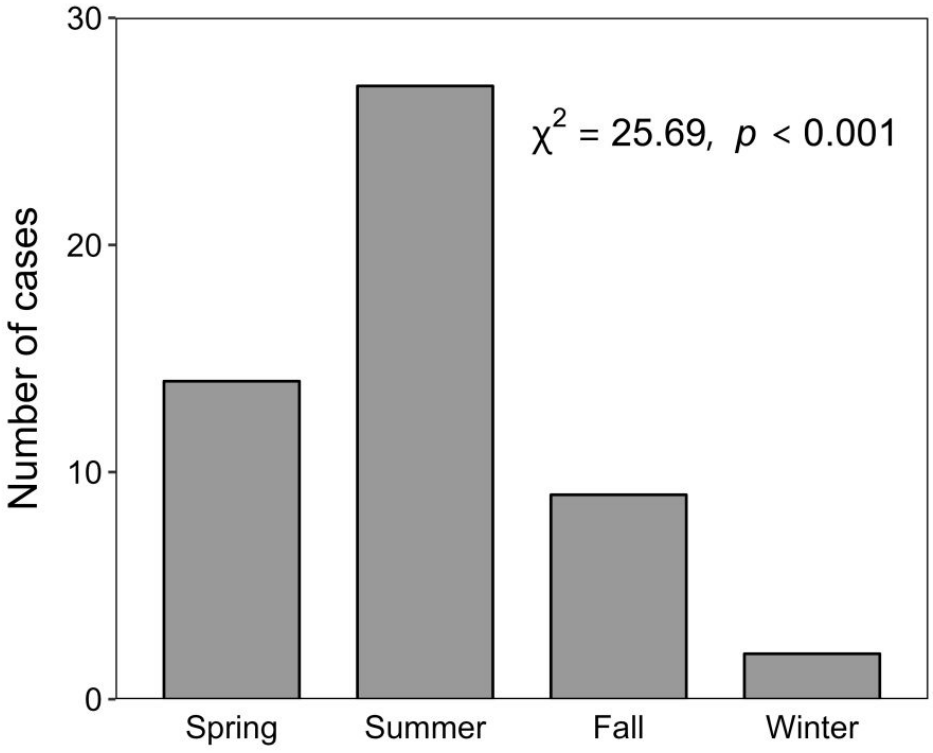

Figure S2. The number of ant hitchhiking cases in each season across the study period (spring: March–May; summer: June–August; fall: September–November; winter: December–February).

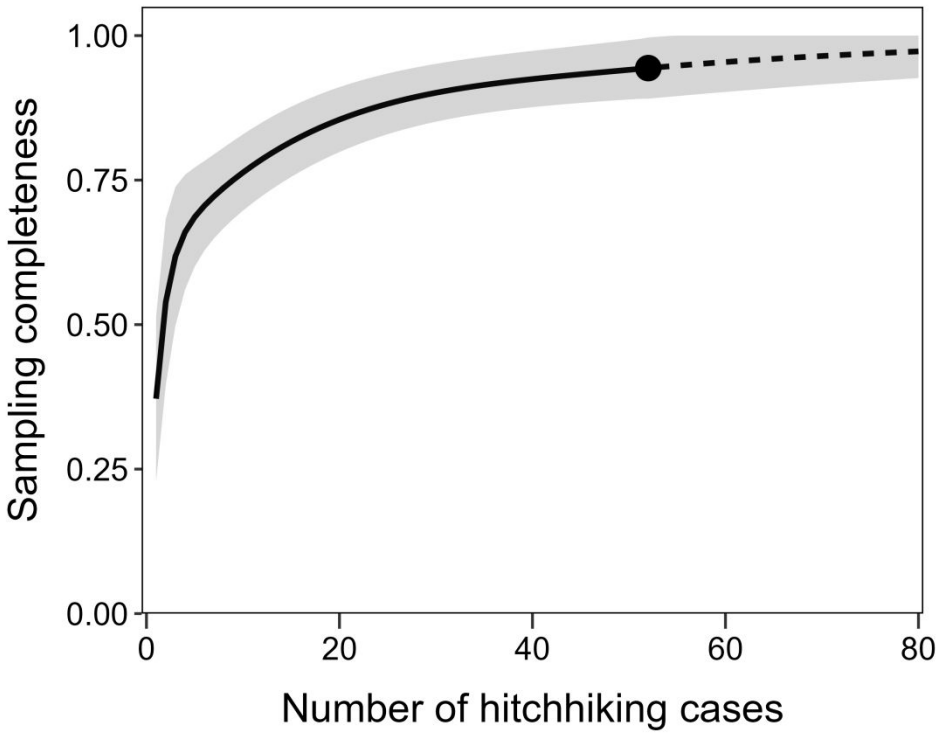

Figure S3. Sampling completeness curve for the ant hitchhiking data. Point indicates the observed sampling completeness estimate; solid line represents the rarefied sampling completeness estimates; dotted line represents the extrapolated sampling completeness estimates; shaded area represents 95% confidence intervals of the estimates.