**Title**

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**

Species hitchhiking on human transportation objects such as vehicles can facilitate long-distance dispersal of organisms, allowing increased probability 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. 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 a vehicle 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 colder seasons (fall and winter). To our knowledge, this study represents the first efforts 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**

The increases in human transportation activities over the past few decades have had a wide range of impacts on human societies, biodiversity, and the environment (Hulme 2009, Banks et al. 2015). One of the ecological consequences of human transportation 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 and potentially facilitate successful biological invasions (Ward et al. 2006, Von der Lippe and Kowarik 2007, Wilson et al. 2009, Auffret et al. 2014, Gippet et al. 2019).

Various terrestrial organisms, including both animals and plants, have been documented to hitchhike on vehicles. For example, plant seeds attached on/in cars and tire surface can be dispersed over long distances (Von der Lippe and Kowarik 2007, Ansong and Pickering 2013); in some cases, the seeds can remain attached on vehicles for a voyage of hundreds kilometers (Taylor et al. 2012). Exotic earthworms have been introduced into the boreal forests of western Canada through vehicle transportation (Cameron et al. 2007). Insects of various life stages have also been recognized to be a frequent hitchhiker 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, Meurisse et al. 2019). Dispersal range of adult flying insects can be even boosted via hitchhiking on vehicles: the tiger mosquito (*Aedes albopictus*) can travel in cars and move across provinces in Spain (Eritja et al. 2017).

Ants have been reported to disperse via human cultural and commercial activities (Bertelsmeier et al. 2017). This is especially true for major invasive pest ants including the red imported fire ant (*Solenopsis invicta*), little fire ant (*Wasmannia auropunctata*), and Argentine ant (*Linepithema humile*). 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 such as soil, potted plants, and timbers (Jetter et al. 2002, Vogt and Kozlovac 2006, Chen et al. 2019). The focus has long been concentrated on materials infested and transported by agricultural and construction vehicles. However, reports on ants actively hitchhiking on vehicles—meaning that ants take the initiative to get onto the vehicle, 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 of 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 launched on a major social media Facebook and characterized the spatial and temporal patterns of ant hitchhiking incidences. This study represents the first effort to profile active ant hitchhiking on vehicles. Potential ecological implications will be discussed.

**Materials and Methods**

*Data collection and analysis*

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 a case involving their own vehicle infested with ants of different caste (e.g., worker and queen) or life stage (e.g., brood). Each contributor was inquired about the parking date and location of the vehicles parked, parking duration (from the time when the vehicle was parked on the site to the time when the ant hitchhiking was observed), vehicle type (car or scooter), intended destination (which was used to estimate the distance, refers to how far a given hitchhiking ant can travel if it manages to arrive with the vehicle), weather conditions, surrounding environment (e.g., whether there was any trees nearby), and a photo of the ant 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 ant hitchhiking data. A set of survey questions was posted for the contributors to provide the aforementioned information regarding the hitchhiking events. The data collected 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 using the Pearson's chi-square test. We also quantified the sampling completeness of our data using the R package “iNext”. All recorded cases and the associated variables were provided in the Supplementary Data.

**Results**

In total, 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). Nine species were recorded; two were native and seven were exotic/invasive (Table 1). The majority of species were arboreal or semi-arboreal ants (Table 1). 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 events (*n* = 30) occurred within a day. The average distance between the parking location and the intended destination of the vehicle was around 60 km for the 17 cases where the contributors provided their intended destinations, with 13 cases having a distance larger than 30 km (Fig. S1). (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.) The numbers of reported cases differed significantly among seasons (χ2 = 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 sampling completeness of the data was XXX.

**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 are often dominant and 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 than native ants. One major consequence of ant hitchhiking on vehicles is the accelerated spread of exotic/invasive ants. The distance between a parking location and an intended destination can be up to a few hundred kilometers (e.g., from Taitung County in southern Taiwan to Miaoli County in central Taiwan; Fig. S1), largely exceeding the natural movements achievable through dispersal. Hitchhiking events can take place within several hours after parking, during which workers often carry brood along with queen(s) and move together to the vehicles. (We were able to identify at least three cases with queen(s) and eight cases with brood based on the photos provided by the contributors.) This suggests that ant hitchhiking is not merely foraging behavior. Instead, it appears to be a colonization attempt, potentially driven by high population pressure and the availability of vehicles offering preferred nesting spots, such as pre-existing physical spaces 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 (Hsu et al. 2022) and is frequently observed to move nests from tree trunks to nearby pre-existing artificial structures with crevices (which are readily available in vehicles).

Based on our analysis, we propose three factors that may play critical roles in determining a successful ant hitchhiking event (i.e., from moving onto a vehicle to arriving at a new place) (Fig. 2). First, ants need to encounter a vehicle, which largely depends on their searching or 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) (Yanoviak and Kaspari 2000, Hahn and Wheeler 2002, Hashimoto et al. 2010). As vehicle operators often prefer parking sites with tree cover (McPherson 2001) (especially during the warmer seasons), arboreal ants’ encounter with vehicles can be largely increased. In fact, there were plenty of instances in our records where the vehicles’ surface came into contact with the leaves and twigs of the nearby trees, creating physical pathways for ants to move onto the vehicles and thus increasing the opportunities for hitchhiking.

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. Even if the ants come directly from the trees via twigs or branches that touch the vehicle, they still need to be capable of moving along the vehicle surface. The climbing and moving performance of ants is determined by the morphological characteristics of the leg segments (Beutel et al. 2020). For instance, the fine hair arrays on the tarsus can increase the friction forces during vertical climbing (Endlein and Federle 2015). 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, have straight pretarsal claws and lack adhesive pads as well as tarsal hairs. Therefore, they are less capable of moving on smooth surfaces such as vehicle paint (Orivel et al. 2001, Billen et al. 2017). The ability of climbing and holding onto the vehicle may partially explain the over-representation of arboreal ants in our records.

Third, ants need to be able to colonize the vehicle after moving onto it. The temperature on the surface and in the interior of the vehicle can increase dramatically when exposed to sunlight, especially in the summer. In our records, a high proportion of the hitchhiking incidences occurred during the warmer seasons (Fig. S2), suggesting that the thermal tolerance of hitchhiking species may play an important role in determining their colonization success. For instance, a study involving the invasive brown marmorated stink bug (*Halyomorpha halys*) showed that the insect’s thermal tolerance was critical for surviving a trans-Pacific ship voyage (Nixon et al. 2019). Since arboreal ants are generally more heat- and drought-tolerant compared to ground-dwelling ants (Hood and Tschinkel 1990, Bujan et al. 2016, Leahy et al. 2022), rendering them more likely to survive the high temperature on or in the vehicle, which translate into higher propagule pressure and thus the probability of successful establishment at the destination (Lockwood et al. 2005, Simberloff 2009).

To our knowledge, this is the first report profiling active ant hitchhiking on vehicles via citizen science efforts. The over-representation of arboreal and semi-arboreal ants in our records suggests the possibility 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 hitchhiking on vehicles.

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**Conflict of interest**

The authors declare no conflict of interest regarding this manuscript.

**Author contributions**

FCH and GCH conceived the ideas, collected the data, analyzed the data, and wrote the first draft of the manuscript; CCSYconceived the ideas and wrote the first draft of the manuscript; all authors revised the manuscript and approved the final version for publication.

**Data availability statement**

Data and code used in this manuscript are publicly available on Zenodo: DOI.

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**Figures**

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

Illustration

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