**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 vehicle 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. In total, 52 cases of ant hitchhiking on a vehicle were reported between 2017 and 2023, with nine ant species involved. Seven out of the nine species with being exotic/invasive. Arboreal or semi-arboreal ant speceis, 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 warm seasons (i.e., spring and summer) than in cold seasons (i.e., 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), and in some cases seeds can even 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*) are found to lay eggs on the surface of shipping containers, trucks and various vehicles, and later arrive at 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*) as a well-established body of literature has demonstrated that the rapid range expansion of these ants are 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). Given the focus has been long concentrated on infested materials transported by agricultural and construction vehicles, reports on ants “actively” hitchhiking on civilian vehicles and the metadata of these incidences (e.g., seasonality or common hitchhiker ant species) are lacking. Filling this knowledge gap would aid the development of effective management strategies to mitigate ant invasions resulting from hitchhiking.

To better understand this phenomenon, we collected active ant hitchhiking cases in Taiwan from via a citizen science project on a major social media (Facebook) and characterize the spatial and temporal patterns of ant hitchhiking incidences in Taiwan. This study represents the first efforts of profiling active ant hitchhiking on vehicles. Potential ecological implications will also be discussed.

**Materials and Methods**

*Data collection and analysis*

There are two phases of data collection. In the initial phase of data collection (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., queen) or life stage (e.g., brood). A contributor provided the parking date and location of the vehicles parked, parking duration (from the time when the vehicle was parked on site to when the ant hitchhiking was observed which is often when the person was about to leave the site), vehicle type (car or scooter), intended destination (which was used to estimate distance 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 from users. A contributor was asked to answer all listed standardized survey questions identical to those in the initial phase. 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 following 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. All recorded cases and the associated variables were provided in the Supplementary Data.

**Results**

In total, we received 52 cases of active ant hitchhiking on cars (*n* = 44) and scooters (*n* = 8) between 2017 and 2023, with the majority of them reported from central and northern Taiwan (Fig. 1). Nine species were recorded, among which 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 few hours to over a month, almost 60% of the hitchhiking events (*n* = 30) occurred within a day. The numbers of reported cases differed significantly among seasons (χ2 = 25.69, *df* = 3, *P* < 0.001) and were higher in the warmer seasons (spring and summer) compared to the colder seasons (fall and winter) (Fig. 2).

**Discussion**

In this study, we provide the first qualitative and quantitative analysis of ant hitchhiking behavior using citizen science data. Our analysis indicates that exotic/invasive ants were major “hitchhikers” as they are overrepresented in our dataset. Exotic ants often are 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 ais that /invasive ant can be accelerated The travel distance between a parking location and an intended destination can be up to a few hundred kilometers (e.g., from Nantou County in central Taiwan to Pingtung County in southern Taiwan, Fig. S1), which are largely beyond the distance through natural 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. This suggests that ant hitchhiking is not merely foraging behavior but also a colonization attempt, potentially driven by high population pressure or vehicles offering preferred nesting spots, such as pre-existing physical space or cervices. 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 usually found to move nest from tree trunks to nearby pre-existing artificial structures with cervices, which vehicles highly resemble to.

Based on our analyses, we argue that at least three factors may play a critical role in determining a successful ant hitchhiking event (i.e., from moving on a vehicle to arriving in a new place) (Fig. 3). First, ants need to encounter vehicles, which largely depends on their searching or exploratory behavior. Significantly more hitchhiking cases were reported in spring and summer compared to fall and winter (Fig. 2), which is consist with ants generally foraging more actively under warmer conditions (Parr and Bishop 2022). Interactions between human behaviors and ant habitat may contribute to higher vehicle encountering probability of ants. Arboreal ants typically exhibit frequent foraging activities and territorial patrolling due to resource limitations within tree canopies (particularly nitrogen availability) (Yanoviak and Kaspari 2000, Hahn and Wheeler 2002, Hashimoto et al. 2010), coupled with vehicle operators’ preference of selecting sites with tree cover to park (McPherson, 2001) (especially during the warmer seasons), arboreal ants’ encounter with vehicles can be largely encouraged. Furthermore, there were plenty of instances in our dataset where the vehicle's surface came into contact with the leaves and twigs of trees, which creating physical pathways for ants to move onto a vehicle and subsequently increasing the opportunities for hitchhiking.

Second, ants need to climb or hold onto a vehicle after locating it. The metallic paint on vehicle surface is likely slippery and may potentially selects for species with good climbing/gripping abilities. Even if the ants come onto the vehicles directly from the trees via twigs or branches that touch the vehicles, they still need to be capable of moving on 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, however, have straight pretarsal claws and lack adhesive pads as well as tarsal hairs, and therefore they are less capable of moving on smooth vertical surfaces such as vehicle paint (Orivel et al. 2001, Billen et al. 2017). The ability of being able to climb and hold onto vehicle may explain the overrepresentation of arboreal ants in our dataset.

Third, ants need to be able to colonize vehicles after moving onto them. The temperature on the surface and in the interior of vehicles can increase dramatically when exposing to sunlight, especially in the summer. In this study, a high proportion of the hitchhiking incidences occurred during the warmer seasons (Fig. 2), 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 its thermal tolerance is critical for surviving a trans-Pacific ship voyage (Nixon et al. 2019). 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 vehicles. Consequently, this may increase the quality of 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 ant hitchhiking on vehicles via citizen science efforts. The overrepresentation of arboreal and semi- arboreal ants in our dataset suggests the possibility of establishing a predictive framework for forecasting future hitchhiker based on behavioral, morphological, physiological, and ecological traits of species of interest, which facilite 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.

Reference

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.

Banks, N. C., D. R. Paini, K. L. Bayliss, and M. Hodda. 2015. The role of global trade and transport network topology in the human‐mediated dispersal of alien species. Ecology Letters **18**:188-199.

Bertelsmeier, C., S. Ollier, A. Liebhold, and L. Keller. 2017. Recent human history governs global ant invasion dynamics. Nature ecology & 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.

Billen, J., M. S. Al-Khalifa, and R. R. Silva. 2017. Pretarsus structure in relation to climbing ability in the ants Brachyponera sennaarensis and Daceton armigerum. Saudi Journal of Biological Sciences **24**:830-836.

Bujan, J., S. P. Yanoviak, and M. Kaspari. 2016. Desiccation resistance in tropical insects: causes and mechanisms underlying variability in a Panama ant community. Ecology and Evolution **6**:6282-6291.

Cameron, E. K., E. M. Bayne, and M. J. Clapperton. 2007. Human-facilitated invasion of exotic earthworms into northern boreal forests. Ecoscience **14**:482-490.

Chen, S., H. Chen, and Y. Xu. 2019. Safe chemical repellents to prevent the spread of invasive ants. Pest Management Science **75**:821-827.

Endlein, T., and W. Federle. 2015. On heels and toes: how ants climb with adhesive pads and tarsal friction hair arrays. PloS ONE **10**:e0141269.

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.

Hahn, D. A., and D. E. Wheeler. 2002. Seasonal foraging activity and bait preferences of ants on Barro Colorado Island, Panama1. Biotropica **34**:348-356.

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.

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

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**.

Hulme, P. E. 2009. Trade, transport and trouble: managing invasive species pathways in an era of globalization. Journal of Applied Ecology **46**:10-18.

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.

Lockwood, J. L., P. Cassey, and T. Blackburn. 2005. The role of propagule pressure in explaining species invasions. Trends in ecology & evolution **20**:223-228.

Meurisse, N., D. Rassati, B. P. Hurley, E. G. Brockerhoff, and R. A. Haack. 2019. Common pathways by which non-native forest insects move internationally and domestically. Journal of Pest Science **92**:13-27.

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.

Simberloff, D. 2009. The role of propagule pressure in biological invasions. Annual Review of Ecology, Evolution, and Systematics **40**:81-102.

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.

Von der Lippe, M., and I. Kowarik. 2007. Long‐distance dispersal of plants by vehicles as a driver of plant invasions. Conservation Biology **21**:986-996.

Ward, D. F., J. R. Beggs, M. N. Clout, R. J. Harris, and S. O’Connor. 2006. The diversity and origin of exotic ants arriving in New Zealand via human‐mediated dispersal. Diversity and Distributions **12**:601-609.

Wilson, J. R., E. E. Dormontt, P. J. Prentis, A. J. Lowe, and D. M. Richardson. 2009. Something in the way you move: dispersal pathways affect invasion success. Trends in ecology & evolution **24**:136-144.

Yanoviak, S., and M. Kaspari. 2000. Community structure and the habitat templet: ants in the tropical forest canopy and litter. Oikos **89**:259-266.

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**

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

Illustration

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