**Title**

Catch a free ride with me: A report on ant hitchhiking on vehicles in Taiwan and its ecological implications

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**Abstract**

Species hitchhiking on human transportation objects can facilitate long-distance dispersal of organisms, allowing them to colonize new areas and thus increasing the probability of biological invasions. In Taiwan, there have been observations of active species hitchhiking on mobile vehicles by ants, yet no study has examined this behavior. Here, we provide the first report on ant hitchhiking using citizen science data. In total, 45 cases belonging to eight species of ant hitchhiking on cars (*n* = 39) and scooters (*n* = 6) were collected between 2017 and 2023. Specially, the black cocoa ant (*Dolichoderus thoracicus*) constituted over half of the reported cases (*n* = 26). Among the hitchhiking ant species, six could be considered exotic and seven were arboreal. The parking duration of the vehicles on which the ants hitchhiked ranged from several hours to over a month, with around 65% (*n* = 28) of the cases occurring within a day. Moreover, there were more cases reported in spring and summer compared to fall and winter. We encourage future studies to examine the behavioral, morphological, physiological, and ecological traits of ants that underlie the success of hitchhiking events to better predict the spread of exotic ants and to develop management strategies for preventing their biological invasions.

**Keywords**

arboreal ants, biological invasions, citizen science, exotic species, human-mediated dispersal, species hitchhiking, transportation

**Introduction**

The increases in human transportation activities over the past few decades have had a wide range of impacts on human societies, living organisms, 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 through mobile vehicles. Such “hitchhiking” can lead to long-distance dispersal of species beyond their natural ranges and potentially facilitate 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, be it animals or plants, have been documented to hitchhike on vehicles. For example, plant seeds can disperse to new places by attaching to car and tire surface (Von der Lippe and Kowarik 2007, Ansong and Pickering 2013), and the seeds can retain on the vehicles for hundreds of kilometers under certain conditions (Taylor et al. 2012). Exotic earthworms have been introduced into the boreal forests of western Canada through vehicle transportation (Cameron et al. 2007). Many insects also hitchhike on vehicles. For instance, gypsy moth (*Lymantria dispar*) may lay eggs on the surface of shipping containers and trucks, and later arrive at the destination as larvae (Gray 2017, Meurisse et al. 2019). The tiger mosquito (*Aedes albopictus*) can travel in cars and move across provinces (Eritja et al. 2017).

In recent years, observations of ants actively hitchhiking on vehicles in Taiwan have been reported. These observations have shown that hitchhiking may facilitate the spread of ants to new areas. However, no studies have investigated such an active ant hitchhiking behavior. To better understand this phenomenon, we collected ant hitchhiking cases from the social media Facebook via citizen science efforts and examined the spatial and temporal patterns of ant hitchhiking in Taiwan. Our aim is to provide the first official report on ant hitchhiking on vehicles and discuss its potential ecological implications.

**Materials and Methods**

*Data collection and analysis*

In the initial phase of this study (2017–2022), instances of ant hitchhiking on vehicles were gathered from Facebook by distributing information regarding ant hitchhiking to the users. When a user responded, we asked the person to provide the parking date and location of the vehicles, the parking duration (the time period between the vehicle was parked and the ant hitchhiking was observed), the vehicle type (car or scooter), the intended destination, the weather conditions, the surrounding environment (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 was established to systematically collect ant hitchhiking data from users. Standardized survey fields were provided for observers to report the aforementioned information on hitchhiking cases. The data collected from the two phases were combined as the final data for analysis.

We classified the ant species as “arboreal”, “semi-arboreal”, or “ground-dwelling” based on their nesting sites and foraging habits. The number of reported cases in the four seasons (spring: March–May; summer: June–August; fall: September–November; winter: December–February) was tested using a Pearson's chi-square test. All recorded cases and the associated variables were provided in the Supplementary Data.

**Results**

In total, we collected 52 cases of ant hitchhiking on cars (*n* = 44) and scooters (*n* = 8) between 2017 and 2023, with the majority of them from central and northern Taiwan (Fig. 1). Nine species were recorded, among which two were native and seven were exotic (Table 1). Eight species were arboreal and semi-arboreal ants (Table 1). One species in particular, the black cocoa ant (*Dolichoderus thoracicus*), constituted around 60% the reported cases (*n* = 31). The parking duration of the vehicles on which the ants hitchhiked ranged from less than a half day to over a month; more than half of the hitchhiking events (*n* = 30) occurred within a day. The number of reported cases differed among the four seasons (χ2 = 25.69, *df* = 3, *P* < 0.001) and were higher in spring and summer compared to fall and winter (Fig. 2).

**Discussion**

Ant hitchhiking on vehicles can be a potential pathway for the spread of exotic species (Table 1). In some cases, the travel distance between the parking location and the intended destination can be as long as a few hundred kilometers (from Nantou County in central Taiwan to Pingtung County in southern Taiwan), which largely exceeds the dispersal distance achievable through natural movements. Furthermore, hitchhiking events can take place within several hours, during which the workers would carry eggs and larvae with queen(s) to the vehicles, suggesting that such hitchhiking is not a foraging behavior but rather a colonization attempt, potentially driven by high population pressure. In fact, the most frequently reported hitchhiking species, the black cocoa ant (*D*. *thoracicus*), exhibits notably high local densities in central Taiwan, potentially acting as a driving force behind their dispersal and colonization of artificial structures (vehicles). Of particular significance is the recognition of black cocoa ant in central Taiwan as "cryptic invasive populations" (Hsu et al. 2022). Thus, the role of vehicles in facilitating the dispersal of invasive populations cannot be underestimated, emphasizing the need for comprehensive monitoring and management efforts to control the impact of these invasive populations.

Various factors determine a successful ant hitchhiking event (Fig. 3). First, ants need to encounter vehicles, which depends largely on their searching behavior. Ants are generally more active under warmer conditions (Parr and Bishop 2022), potentially leading to more hitchhiking cases in spring and summer compared to fall and winter (Fig. 2). Moreover, species with different habitat associations may differ in the probability of encountering vehicles. As a consequence of resource limitations within tree canopies, notably in terms of nitrogen availability, arboreal ants typically exhibit frequent foraging activities and territorial patrolling (Yanoviak and Kaspari 2000, Hahn and Wheeler 2002, Hashimoto et al. 2010). Furthermore, there are instances when the vehicle's surface comes into contact with leaves and twigs of plants, thereby creating channels for ants. This occurrence serves to increase the opportunities for ant hitchhiking.

Second, ants need to climb onto the vehicles after locating them. The metallic paint of vehicle surface could present a slippery barrier to ants, and only species with good climbing abilities are able to overcome this hurdle. The climbing 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 for 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. On the other hand, ground-dwelling ants 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 (Orivel et al. 2001, Billen et al. 2017).

Third, ants need to be capable of colonizing the vehicles after moving onto them. The thermal tolerance of species plays a critical role in this because ants have to tolerate the high temperature of the vehicle surface and interior before arriving at the destination and dispersing to new areas. 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), and therefore they are more likely to utilize artificial structures and hitchhike on vehicles. Furthermore, car color may influence the ants’ colonization attempt and success as it affects the temperature of the vehicles, particularly under sunlight exposure.

To our knowledge, this is the first report on ant hitchhiking on vehicles via citizen science. Despite limited reported cases, our study nonetheless reveals interesting patterns in ant hitchhiking, and we have endeavored to engage the wider community in citizen science efforts as a cost-efficient method for hitchhiking data collection. We encourage future studies to examine the behavioral, morphological, physiological, and ecological traits of exotic species versus their native relatives to better understand the determinants underlying the success of hitchhiking events. Hopefully, this can help predict the spread of exotic ants and develop management strategies for preventing their biological invasions.

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**Conflict of interest**

The authors declare no conflict of interest regarding this manuscript.

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**Tables and Figures**

Table 1. The status, habitat association, and the number of reported hitchhiking cases of the ant species in this study

|  |  |  |  |
| --- | --- | --- | --- |
| Species | Status | Habitat association | Cases |
| *Polyrhachis dives* | Native | Arboreal | 2 |
| *Nylanderia* sp. | Native | Ground-dwelling | 1 |
| *Dolichoderus thoracicus* | Exotic  (cryptic invasion) | 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 |

Figure 1. (a) A map of the ant hitchhiking cases in Taiwan and (b–c) example photos of ant hitchhiking on vehicles.

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Figure 2. The number of ant hitchhiking cases in each season (spring: March–May; summer: June–August; fall: September–November; winter: December–February).

Illustration

Figure 3. The determinants of a successful ant hitchhiking event. See *Discussion* for more details.