



**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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3 **Abstract**

- 4 1. Species hitchhiking on human transportation objects such as vehicles can  
5 facilitate long-distance dispersal of organisms, allowing increased probabilities of  
6 successful biological invasions. In Taiwan, there have been observations of ants  
7 actively moving onto motor vehicles (defined as “ant hitchhiking” hereafter), yet  
8 no study has explored this phenomenon.
- 9 2. Here, we provide the first qualitative and quantitative report on ant hitchhiking  
10 behavior using citizen science data. From 2017 to 2023, 52 cases of ant  
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12 another eight cases with brood), attributed to nine species. Seven out of the nine  
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16 hitchhiked ranged from several hours to over a month (30 cases occurred within  
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- 19 3. To our knowledge, this study represents the first effort to profile active ant  
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21 biotic factors that determine the success of hitchhiking events to better predict  
22 the spread of exotic/invasive ants and to develop effective management  
23 strategies for preventing their biological invasions.

24 **Keywords**

25 biological invasions, citizen science, exotic species, human-mediated dispersal,  
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## 27 **Introduction**

28 An ecological consequence of human transportation activity is the transfer of  
29 organisms to a new area via mobile equipment and related vehicles. Such  
30 “hitchhiking” can lead to long-distance dispersal of species beyond their natural  
31 ranges, potentially facilitating biological invasions (Auffret et al. 2014, Gippet et al.  
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42 Invasive ants have been reported to disperse via human cultural and  
43 commercial activities (Bertelsmeier et al. 2017). A well-established body of literature  
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45 transportation of ant-infested agricultural, horticultural, and construction materials  
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48 reports on ants actively hitchhiking on vehicles—ants take the initiative to get onto

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10 52 knowledge gap would help develop effective management strategies to mitigate ant  
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12 53 invasions resulting from hitchhiking.

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15 54 To better understand this phenomenon, we collected active ant hitchhiking  
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17 55 cases in Taiwan via a citizen science project and characterized the spatial and  
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20 56 temporal patterns of ant hitchhiking incidences. Potential ecological implications will  
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22 57 be discussed.

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25 58 **Materials and Methods**

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28 59 The data collection consisted of two phases. In the first phase (2017–2022), cases of  
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30 60 ant hitchhiking on vehicles were gathered from Facebook where general public  
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32 61 shares cases involving their own vehicles infested with ants of different castes (e.g.,  
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34 62 worker and queen) or life stages (e.g., brood). Each contributor provided the parking  
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38 64 was parked to the time when the ant hitchhiking was observed), vehicle type (car or  
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42 66 could travel if it managed to arrive with the vehicle), weather conditions, surrounding  
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44 67 environment (e.g., whether there was any tree nearby), and a photo of the ants for  
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46 68 species identification. In the second phase of this study (2023), a dedicated  
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49 69 Facebook group (<https://www.facebook.com/groups/577051257470900>) was  
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56 72 (at least 20 individuals) present on the vehicles (Supplementary Video 1). The data  
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from the two collection 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 data 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). Hitchhiking events not only occurred on the surface of vehicles, but in many cases under the hood or in the trunk of both cars and scooters ( $n = 22$ ). Additionally, 10 cases were found in the interior space of vehicles, half of which were the ghost ant, *Tapinoma melanocephalum*. From the photos provided by the contributors, we identified at least three cases with queen(s) and eight cases with brood (note these 11 cases were non-overlapping). 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 (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/invasive 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. Most of the recorded exotic ant species in this study are widely distributed on the island, with the only exception being the exotic black cocoa ant (*D. thoracicus*) that is mainly distributed in central Taiwan (Hsu et al., 2022). The intended destinations of hitchhiking black cocoa ant being scattered across various parts of Taiwan (Fig. S1) indicates that hitchhiking with vehicle may serve a potential pathway contributing to the rapid range expansion of this ant.

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. In most of these cases, we did not find evidence of food resources immediately available on the vehicles. This suggests that ant hitchhiking is less likely to be 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, 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.

It is likely that ant hitchhiking events would be much more common than what has been reported through our Facebook group. We suspect that whether vehicle owners are aware of the Facebook group and/or vehicle owners are willing to report their observations to our Facebook group would play a critical role in the number of incidences we receive for this citizen science project. Nonetheless, we were able to record at least 52 hitchhiking cases with complete information over a seven-year period. Despite a relatively small dataset, the estimated sampling completeness was appropriate (Fig. S3). To our knowledge, this is the first report profiling active ant



171 hitchhiking on vehicles via citizen science efforts, highlighting the importance of  
 172 establishing a predictive framework for forecasting future hitchhikers based on  
 173 behavioral, morphological, physiological, and ecological traits of ant species. Such a  
 174 framework will help facilitate the development of effective management strategies for  
 175 mitigating ant invasions via active hitchhiking on vehicles.

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235   **Figures**

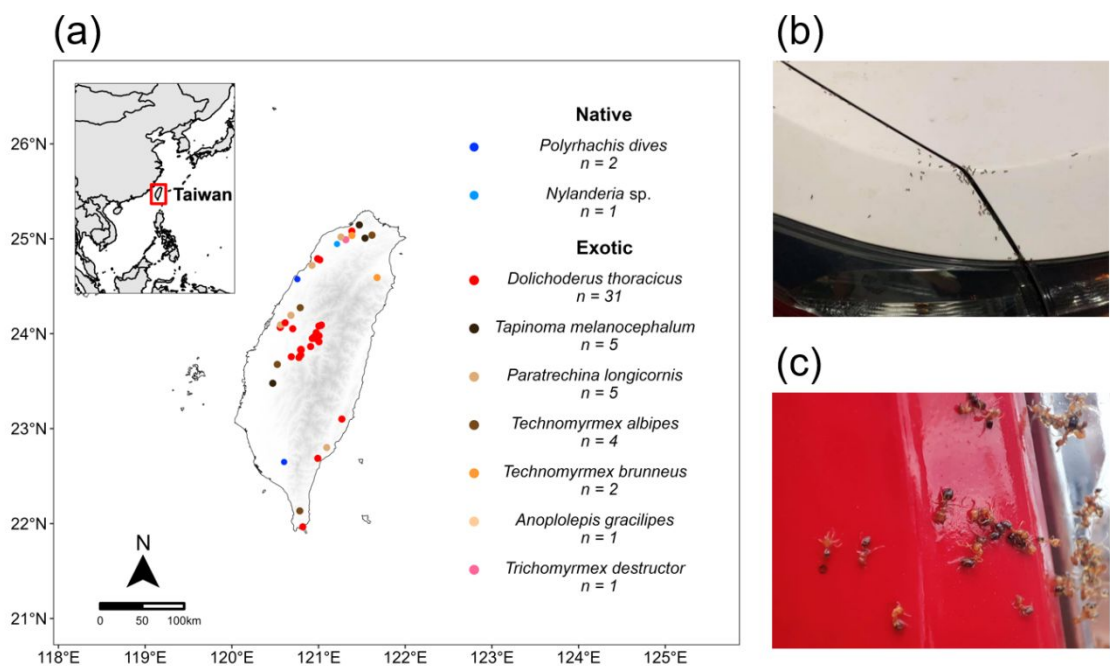
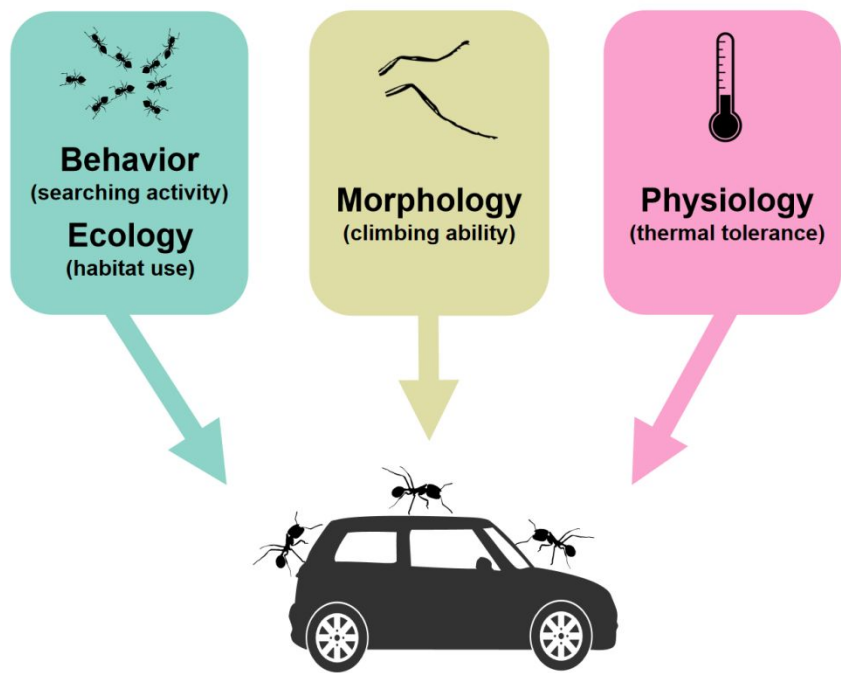


Figure 1. (a) Distribution and species of the ant hitchhiking cases; (b–c) example photos of ant hitchhiking on vehicles.



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

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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 data regarding each ant hitchhiking incidence. All photos and videos were checked and included only when there were groups of ants (at least 20 individuals) present on the vehicles



(Supplementary Video 1). The data from the two collection phases were combined as a single dataset for subsequent analysis.

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## 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). Hitchhiking events not only occurred on the surface of vehicles, but in many cases under the hood or in the trunk of both cars and scooters ( $n = 22$ ). Additionally, 10 cases were found in the interior space of vehicles, half of which were the ghost ant, *Tapinoma melanocephalum*. From the photos provided, by the contributors, we identified at least three cases were found to have with queen(s) and eight cases with brood. (note these 11 cases were non-overlapping). 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

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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/invasive 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. Most of the recorded exotic ant species in this study are widely distributed on the island, with the only exception being the exotic black cocoa ant (*D. thoracicus*) that is mainly distributed in central Taiwan (Hsu et al., 2022). The intended destinations of hitchhiking black cocoa ant being scattered across various parts of Taiwan (Fig. S1) indicates that hitchhiking with vehicle may serve a potential pathway contributing to the rapid range expansion of this ant.

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. In most of these cases, we did not find evidence of food resources immediately available on the vehicles. This suggests that ant hitchhiking is ~~not~~ merely less likely to be 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.

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

156 Third, the temperature on the surface and in the interior of the vehicle can  
157 increase dramatically when exposed to sunlight, especially in the summer, indicating  
158 the thermal tolerance of hitchhiking species may play an important role in  
159 determining their colonization success (Nixon et al. 2019). Arboreal ants are  
160 generally more heat- and drought-tolerant than ground-dwelling ants are (Hood and  
161 Tschinkel 1990, Leahy et al. 2022), which could potentially translate into a higher  
162 probability of successful establishment at the destination due to better survival  
163 chance with high temperatures on or in the vehicle.

164 It is likely that ant hitchhiking events would be much more common than what  
165 has been reported through our Facebook group. We suspect that whether vehicle  
166 owners are aware of the Facebook group and/or vehicle owners are willing to report  
167 their observations to our Facebook group would play a critical role in the number of  
168 incidences we receive for this citizen science project. Nonetheless, we were able to  
169 record at least 52 hitchhiking cases with complete information over a seven-year  
170 period. Despite a relatively small dataset, the estimated sampling completeness was  
171 appropriate (Fig. S3). To our knowledge, this is the first report profiling active ant

172 hitchhiking on vehicles via citizen science efforts, highlighting the importance of  
 173 establishing a predictive framework for forecasting future hitchhikers based on  
 174 behavioral, morphological, physiological, and ecological traits of ant species. Such a  
 175 framework will help facilitate the development of effective management strategies for  
 176 mitigating ant invasions via active hitchhiking on vehicles.

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236   **Figures**

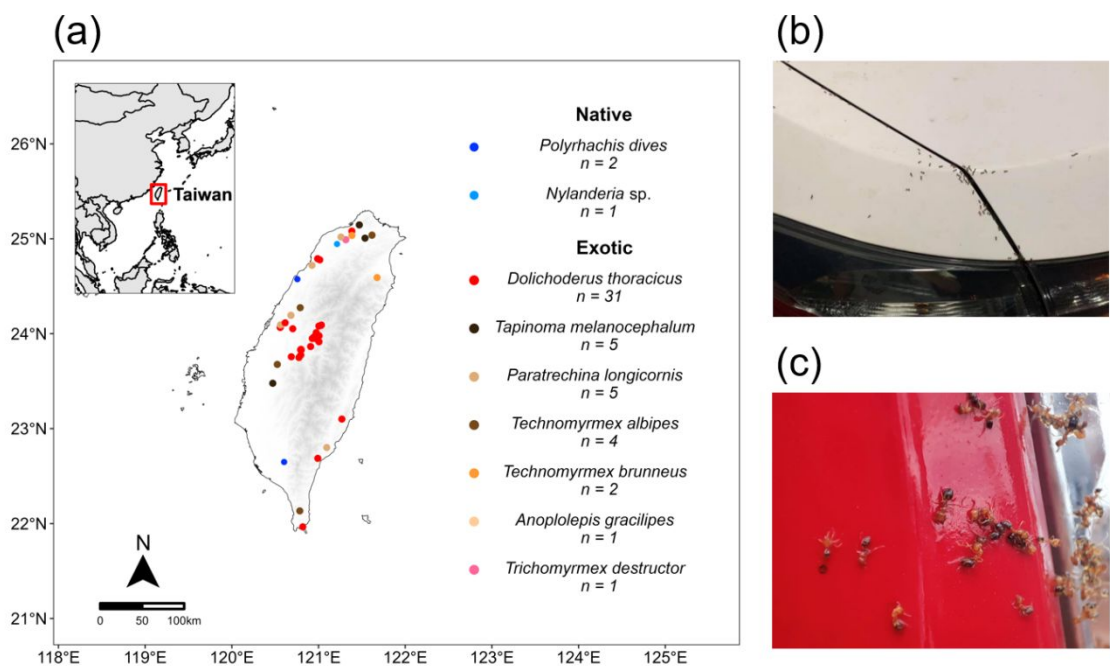
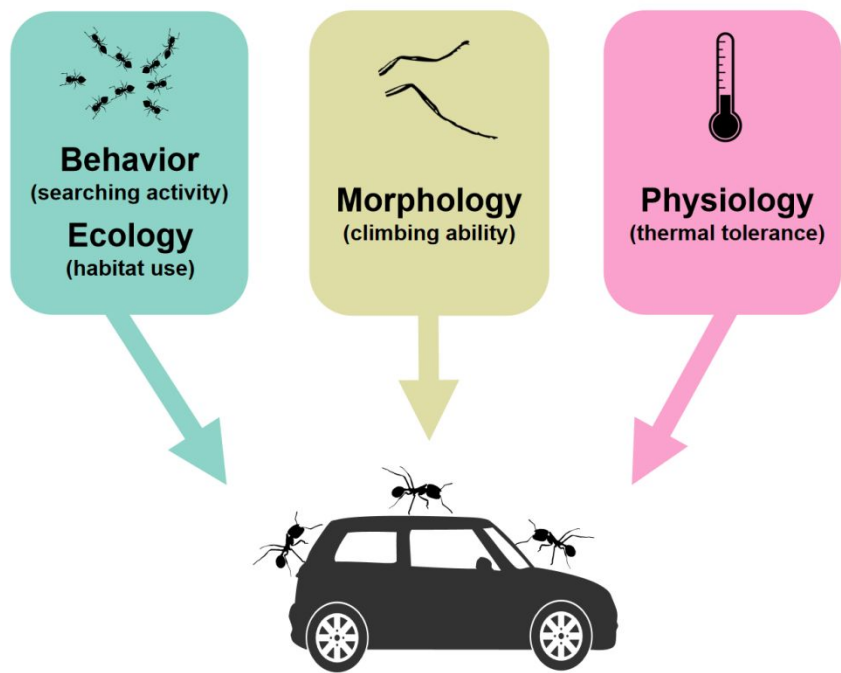


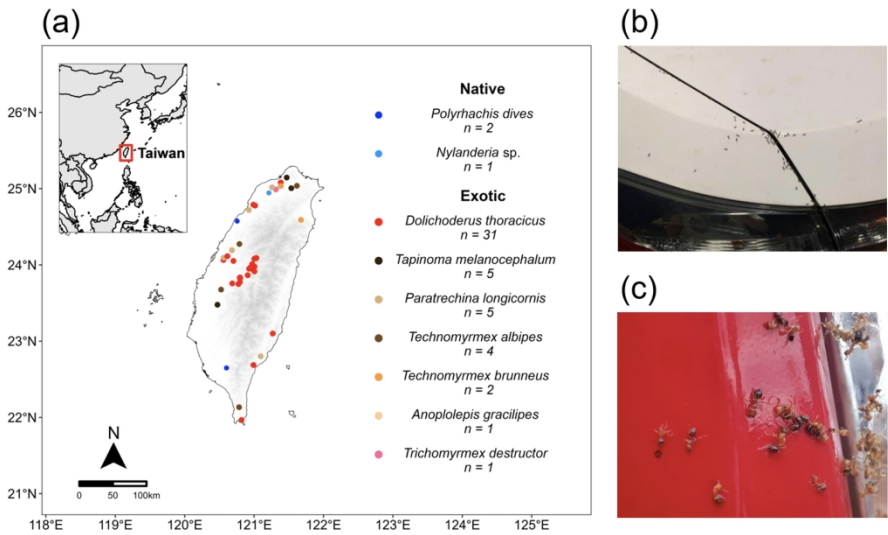
Figure 1. (a) Distribution and species of the ant hitchhiking cases; (b–c) example photos of ant hitchhiking on vehicles.



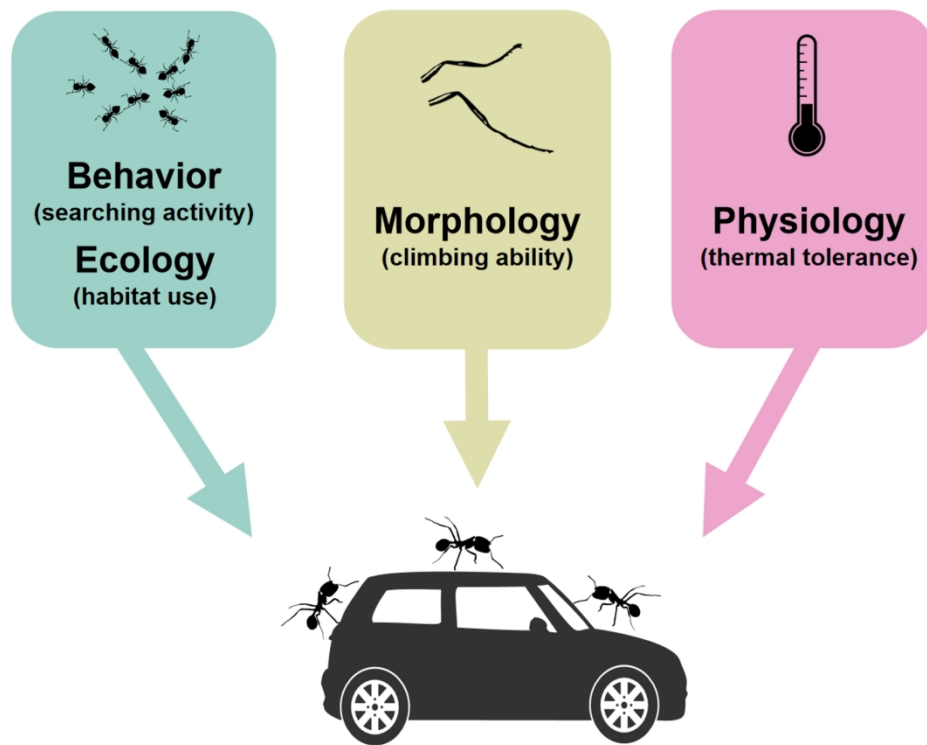


241 Figure 2. Potential factors determining a successful ant hitchhiking event. See  
242 *Discussion* for more details.

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Supplementary Information

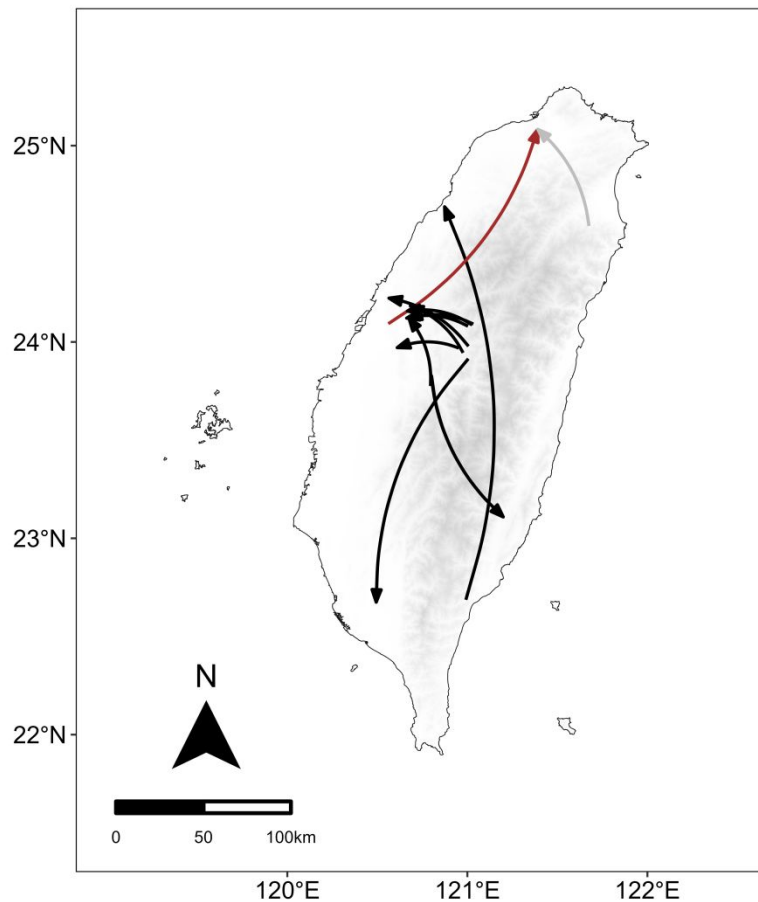
**Video S1.** A white car is being explored by hundreds of black cocoa ant workers

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

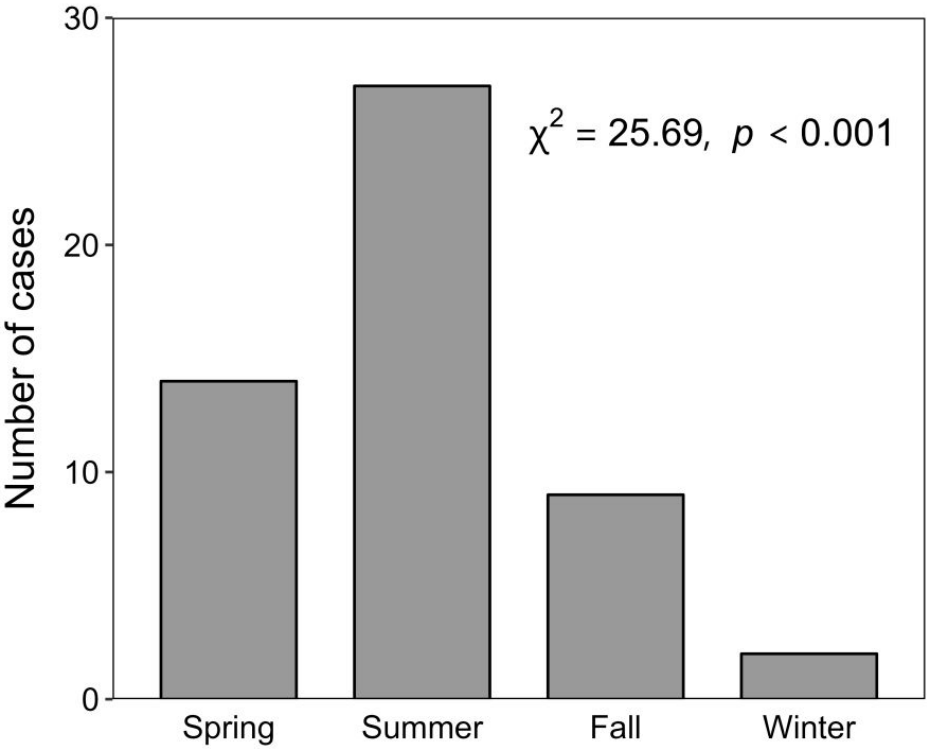
Species	Status	Habitat association	Number of cases
<i>Polyrhachis dives</i>	Native	Arboreal	2
<i>Nylanderia</i> sp.	Native	Ground-dwelling	1
<i>Dolichoderus thoracicus</i>	Exotic*	Arboreal	31
<i>Tapinoma melanocephalum</i>	Exotic	Semi-arboreal	5
<i>Paratrechina longicornis</i>	Exotic	Semi-arboreal	5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

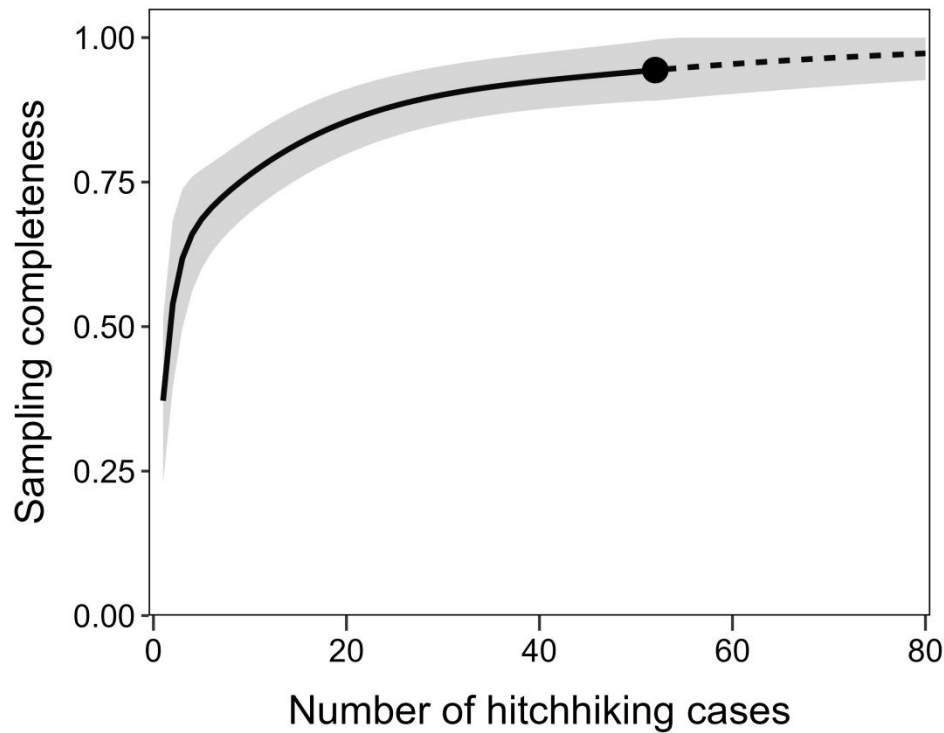


**Figure S1.** The movements of ant-colonized vehicles from the parking locations (arrow end) to the intended destinations (arrowhead) for 13 hitchhiking cases where the distance was larger than 30 km (black: *Dolichoderus thoracicus*; brown: *Tapinoma melanocephalum*; gray: *Technomyrmex brunneus*). 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.