



# Alien Hitchhiker Insect Species Detected on International Vessels Entering Korea in 2023

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## ABSTRACT

We conducted a monitoring study on hitchhiker insect pests aboard international vessels entering Korea in 2023, where we collected 562 individuals from 247 vessels. Of these, 512 individuals were identified as 260 species across 66 families in eight orders, while the remaining 50 individuals were classified at the family level. From the survey of the distribution of these 260 species (512 individuals) identified at the species level, 25 species (39 individuals) across 18 families of six orders were recognized as not-distributed species in Korea. This group included three regulated species (five individuals), *Oryctes rhinoceros* (Scarabaeidae, Coleoptera), *Oecophylla smaragdina* (Formicidae, Hymenoptera), and *Solenopsis invicta* (Formicidae, Hymenoptera) which are listed by the Animal and Plant Quarantine Agency of Korea. Accordingly, continuous quarantine inspections on vessels from native regions are necessary to prevent the entry of these 25 non-distributed species confirmed in this study, in addition to enhancing monitoring around domestic port entry points. As part of the quarantine inspection, we have provided detection information on these 25 non-distributed species in Korea.

**Keywords:** Hitchhiker, Non-distributed species in Korea, International vessel, Monitoring, Quarantine inspection

## Introduction

A hitchhiker organism is temporarily associated with artificial structures or objects without forming a biological host relationship (Toy & Newfield, 2010). The red imported fire ant (*Solenopsis invicta*), detected in sea containers entering Korea, is a globally renowned hitchhiker insect pest (Ascunce *et al.*, 2011; YNA, 2018). In a survey conducted over two years (2018~2019), a total of 1,141 individuals (439 species across 81 families of 12 orders) were detected

in international vessels entering Korea, demonstrating high diversity among hitchhiker insect pests (Kang *et al.*, 2023a). Such invasions, when occurring in large numbers or more frequently, are more likely to become established than those occurring in smaller numbers or less frequently (Lockwood *et al.*, 2005; Johnston *et al.*, 2009, Toy & Newfield, 2010). For instance, *Melanoplus differentialis* (Acrididae, Orthoptera), native to North America, was discovered to have established itself around Onsan Port, Korea, by 2020. It is highly probable that the species has continuously invaded since its initial detection in an international vessel entering Korea in 2018 (Kang *et al.*, 2022).


The detection pattern of hitchhiker insects indicates that over 100 species have been detected annually since the commencement of the actual survey of international vessels entering Korea in 2018. Notably, 14 species (nine families of three orders) identified as not-distributed in

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Korea were found in 2018, 42 species (21 families of seven orders) in 2019, 26 species (21 families of six orders) in 2021, and 38 species (22 families of six orders) in 2022 (Kang *et al.*, 2020, 2021, 2023b, 2024). Due to an increase in detection frequency, there is a growing necessity for long-term monitoring of insect pests hitchhiking on international vessels (Kang *et al.*, 2023a). This study provides biological and hitchhiking data on not-distributed species in Korea detected from international vessels in 2023. Thus, the objectives of this study are to report the not-distributed species detected and identified in 2023 and provide their biological information, including taxonomic details, distribution, and inanimate pathway data.

## Materials and Methods

Samples were collected by visually monitoring the corridor from the bow to the stern of international vessels entering Korean ports. A total of 562 samples consisting of both living and dead individuals were collected. Species identification began with DNA barcoding, followed by morphological re-examination of each individual. The DNA barcodes of the collected insects were compared using the BLAST search method in NCBI and the Identification Engine in the BOLD system ver. 4. Species identification for each sample was conducted using a 2% cutoff rule (Altschul *et al.*, 1990; Hebert *et al.*, 2003, 2004; Ratnasingham & Hebert, 2007). Molecular findings were re-assessed based on morphological characteristics at the para-taxonomic level. The identification results were checked against a website, the National Species List of Korea and Biodiversity of the Korean Peninsula (National Institute of Biological Resources, Ministry of Environment, Korea), to determine whether the species are distributed in Korea (NIBR, 2011, 2019, 2023). For species not distributed in Korea, we catalogued biological information such as taxonomic position, distribution, collection data, and more (Table 1).

## Results

Integrative analyses of the 562 individuals detected from 247 international vessels originating from 27 countries revealed that 512 individuals belonged to 260 species across 66 families of eight orders, with the remaining 50 individuals classified at the family level. Of the 260 species identified, 25 species (39 individuals) were confirmed as not being distributed in Korea. The composition of taxa identified as non-distributed species in Korea showed that Lepidoptera had the highest number of detected individuals, with 13 (11 species), followed by Hemiptera with seven individuals (four species), Hymenoptera with seven individuals (three species), Neuroptera with five individuals (two species), Orthoptera

with four individuals (two species), and Coleoptera with three individuals (three species) (Fig. 1). Notably, three species (five individuals) were recognized as regulated species listed by the Animal and Plant Quarantine Agency in Korea: *Oryctes rhinoceros* (Scarabaeidae, Coleoptera, 1 individ.), *Oecophylla smaragdina* (Formicidae, Hymenoptera, 2 individs.), *Solenopsis invicta* (Formicidae, Hymenoptera, 2 individs.) (Fig. 2, Table 1) (QIA, 2013).

Among 39 individuals of 25 species not found in Korea, 32 individuals belonging to 20 species were detected alive, and seven of these species were detected multiple times: *Hieroglyphus annulicornis* (Acrididae, Orthoptera, 3 individs.), *Chalcopis glandulosa* (Pentatomidae, Hemiptera, 3 individs.), *Chrysoperla suzukii* (Chrysopidae, Neuroptera, 4 individs.), *Formica cunicularia* (Formicidae, Hymenoptera, 3 individs.), *Solenopsis invicta* (Formicidae, Hymenoptera, 2 individs.), *Eumorphobotys eumorphalis* (Crambidae, Lepidoptera, 2 individs.), *Lemyra rhodophilodes* (Erebidae, Lepidoptera, 2 individs.) (Table 1). Given the multiple detections of species in a live condition, there is a need to investigate insect pests in the ports and their adjacent areas.

## Discussion

The International Plant Protection Convention (IPPC) recommended a quarantine inspection plan for sea transports and containers, and introduced a monitoring method from 2016 (IPPC, 2020). In Korea, the study of hitchhiker insect pests by international vessels has been conducted by the Animal and Plant Quarantine Agency of Korea (Kang *et al.*, 2020, 2021, 2023b, 2024). For hitchhiker alien species, the potential for establishment is likely high when entry frequency on a particular route is low, but the number of individuals per entry is large (Toy & Newfield, 2010). Through this study, 39 individuals of 25 species across 18 families and six orders not previously distributed in Korea were detected in 2023, with 32 individuals found alive (Table 1). Of these, seven species were detected with more than two individuals. Compared to a previous studies (Kang *et al.*, 2020, 2021, 2023b, 2024), non-native species in Korea were detected as follows: 22 individuals from 14 species in nine families across three orders in 2018, 67 individuals from 42 species in 21 families across seven orders in 2019, 29 individuals from 26 species in 21 families across six orders in 2021, 71 individuals from 38 species in 22 families across six orders in 2022, and 29 individuals from 25 species in 18 families across six orders in 2023 (Fig. 3). Consequently, the detection frequency of hitchhiker insects is generally increasing.

Comparing the detection patterns of multiple species in 2023 with a previous studies (Kang *et al.*, 2020, 2021, 2023b, 2024), of the species detected in 2022, 10 species (*Patanga succinct* (Acrididae, Orthoptera, 1 individ.),

**Table 1.** Summary data sheet of alien hitchhiker insect species detected on international vessels entering Korea in 2023

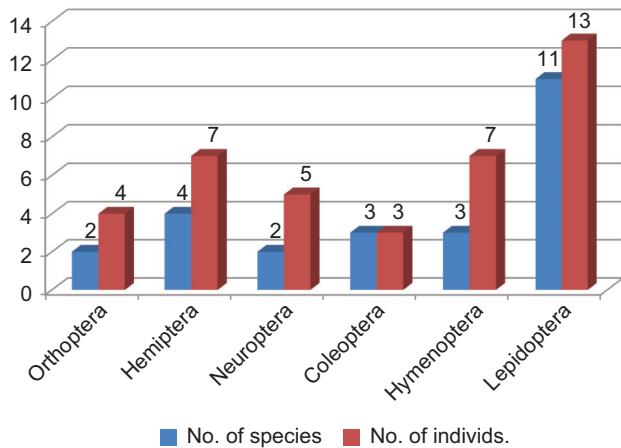
No.	Scientific name	No. of individuals (Live/Dead)	Distribution	Navigation route (Sample no., Vessel no., Outport nation (area) > Transit nation (area) > Destination nation (area), Detection date)	Remarks
<b>Orthoptera</b>					
<b>Acrididae</b>					
1	<i>Hieroglyphus annulicornis</i>	3 (3/0)	India, Thailand, Vietnam, Taiwan, China (Cigliano <i>et al.</i> , 2021)	3307, 9850795, China (Shanghai)>China (Ningbo)>Korea (Busan), Jul-29-2023; 3310, 9687552, China (Keelung)>China (Yangshan)>Korea (Busan), Jul-30-2023; 3321, 9706308, China (Shanghai)>non-stop>Korea (Busan), Jul-28-2023	
2	<i>Patanga succincta</i>	1 (1/0)	India, Pakistan, Thailand, Malaysia, Vietnam, Japan, Philippines, Indonesia (Cigliano <i>et al.</i> , 2021)	3052, 9203576, Japan (Kobe)>Korea (Pyeongtaek)>Korea (Mokpo), Jun-1-2023	2022
<b>Hemiptera</b>					
<b>Alydidae</b>					
3	<i>Daclera levana</i>	1 (1/0)	India, China, Taiwan, Japan (CSFT, 2024)	3162, 9937270, Taiwan (Kaohsiung)>non-stop>Korea (Busan), Jun-22-2023	
<b>Dinidoridae</b>					
4	<i>Cyclopelta parva</i>	2 (0/2)	India, China, Taiwan, Japan (Miyamoto, 1965)	2947, 9184940, China (Yantai)>Korea (Gunsan)>Korea (Gwangyang), Jun-10-2023; 2955, 9714654, China (Yantai)>non-stop>Korea (Yeosu), Jun-7-2023	2022
<b>Fulgoridae</b>					
5	<i>Pyrops sultanus</i>	1 (0/1)	Malaysia, Indonesia (Bourgoin, 2004)	3045, 9636735, Malaysia (Bintulu)>non-stop>Korea (Boryeong), May-23-2023	
<b>Pentatomidae</b>					
6	<i>Chalcopsis glandulosa</i>	3 (3/0)	India, Myanmar, China (Hoberlandt & Safavi, 1981)	2803, 9936513, China (Shanghai)>non-stop>Korea (Busan), May-10-2023; 2806, 9674529, China (Ningbo)>China (Shanghai)>Korea (Busan), May-8-2023; 2807, 9674529, China (Ningbo)>China (Shanghai)>Korea (Busan), May-8-2023	
<b>Neuroptera</b>					
<b>Chrysopidae</b>					
7	<i>Chrysoperla suzukii</i>	4 (4/0)	Japan (Okamoto, 1919)	2783, 9735830, China (Unknown)>Korea (Pohang)>Korea (Gwangyang), Apr-16-2023; 2838, 9502934, Australia (New Castle)>Korea (Yeongheung)>Korea (Samcheonpo), May-25-2023; 2866, 9455715, France (For Sur Mer)>Egypt (Port Said)>Korea (Busan), Jun-4-2023; 3153, 9960148, Japan (Hiroshima)>non-stop>Korea (Busan)	2019
8	<i>Mallada flavimaculus</i>	1 (1/0)	China (Yang <i>et al.</i> , 2005)	2800, 9941996, Japan (Imabari)>non-stop>Korea (Yeosu), Apr-29-2023	

Table 1. Continued.

No.	Scientific name	No. of individuals (Live/Dead)	Distribution	Navigation route (Sample no., Vessel no., Outport nation (area) > Transit nation (area) > Destination nation (area), Detection date)	Remarks
<b>Coleoptera</b>					
<b>Cerambycidae</b>					
9	<i>Rhaphipodus manillae</i>	1 (0/1)	Taiwan (Li <i>et al.</i> , 2014)	3282, 9745938, Japan (Fukuyama) > non-stop > Korea (Yeosu), Jul-20-2023	
<b>Coccinellidae</b>					
10	<i>Harmonia dimidiata</i>	1 (1/0)	North America (introduced), Southern Asia (Poorani & Booth, 2016; ITIS, 2023)	2937, 9333620, Egypt (Port Said) > USA (Free Port) > Korea (Jangseungpo), Jun-6-2023	
<b>Scarabaeidae</b>					
11	<i>Oryctes rhinoceros</i>	1 (0/1)	Southeastern Asia (native), tropical regions of Africa, Asia, North America (invasive) (Hao <i>et al.</i> , 2022)	2782, 9323778, China (Dalian) > non-stop > Korea (Yeosu), Apr-15-2023	Regulated species; 2022
<b>Hymenoptera</b>					
<b>Formicidae</b>					
12	<i>Formica cunicularia</i>	3 (3/0)	Palearctic region (Europe, Asia), Oriental region (India, Pakistan) (AntWiki, 2024a)	2820, 9888869, Japan (Unknown) > non-stop > Korea (Ulsan), May-21-2023; 3204, 9550709, USA (Los Angeles) > USA (San Francisco) > Korea (Yeosu), Jun-19-2023; 3212, 9933559, USA (Corpus Christi) > USA (Loop) > Korea (Yeosu), Jun-25-2023	2019, 2022
13	<i>Oecophylla smaragdina</i>	2 (0/2)	Sri Lanka, India, Nepal, Bangladesh, China, Myanmar, Laos, Thailand, Vietnam, Malaysia, Singapore, Cambodia, Brunei, Philippines, Indonesia, Timor Leste, Papua New Guinea, Solomon Islands, Australia (Wetterer, 2017)	3231, 9717137, Japan (Unknown) > non-stop > Korea (Yeosu), Jun-26-2023; 3232, 9717137, Japan (Unknown) > non-stop > Korea (Yeosu), Jun-26-2023	Regulated species; 2022
14	<i>Solenopsis invicta</i>	2 (2/0)	South America (native), China, Hawaii, Australia, USA (AntWiki, 2024b)	2978, 9832808, China (Unknown) > non-stop > Korea (Yeosu), Jun-4-2023; 2979, 9832808, China (Unknown) > non-stop > Korea (Yeosu), Jun-4-2023	Regulated species
<b>Lepidoptera</b>					
<b>Cossidae</b>					
15	<i>Polyphagozerra coffeae</i>	1 (1/0)	India, Sri Lanka, Laos, China, Taiwan, Japan, Myanmar, Thailand, Vietnam, Moluccas, New Guinea (Holloway, 1986; Savelle, 2014)	2804, 9878503, China (Qingdao) > China (Ningbo) > Korea (Busan), May-19-2023	2022
<b>Crambidae</b>					
16	<i>Eumorphobolys eumorphalis</i>	2 (2/0)	China (Chen <i>et al.</i> , 2018)	2860, 9461051, China (Yangshan) > China (Ningbo) > Korea (Busan), Jun-2-2023; 2935, 9333620, Egypt (Port Said) > USA (Free Port) > Korea (Jangseungpo), Jun-6-2023	2019, 2022

Table 1. Continued.

No.	Scientific name	No. of individuals (Live/Dead)	Distribution	Navigation route (Sample no., Vessel no., Outport nation (area) > Transit nation (area) > Destination nation (area), Detection date)	Remarks
17	<i>Palpita hypohomalia</i>	1 (1/0)	Laos, China (Ko <i>et al.</i> , 2021)	2841, 9865001, Canada (Vancouver)>Korea (Busan)>Korea (Gwangyang), May-12-2023	
<b>Erebidae</b>					
18	<i>Lemyra rhodophilodes</i>	2 (2/0)	Taiwan (Savela, 2014)	2895, 9786499, Japan (Imari)>non-stop>Korea (Busan), May-28-2023; 2896, 9329459, Mexico (Cedros Island)>Japan (Mitsukojima)>Korea (Busan), Jun-2-2023	2018, 2022
<b>Geometridae</b>					
19	<i>Chloroclystis pyrtholopha</i>	1 (1/0)	Australia (Savela, 2014)	3227, 9543342, Korea (Dangjin)>Korea (Pohang)>Korea (Gwangyang), Jun-29-2023	2021
20	<i>Comostola laesaria</i>	1 (1/0)	India, Sri Lanka, Indochina, S.China, Taiwan, Sundaland, N.Australia, Bismarcs (Savela, 2014)	3059, China (Unknown)>non-stop>Korea (Yeosu), Jun-12-2023	
21	<i>Problepsis phoebearia</i>	1 (1/0)	Amur, Primorye, NE.China (Savela, 2014)	2880, 9501344, USA (Charleston)>USA (Savannah)>Korea (Busan), May-27-2023	2022
<b>Limacodidae</b>					
22	<i>Parasa pastoralis</i>	1 (1/0)	India, Pakistan, Bhutan, Nepal, Myanmar, S.China, Taiwan, Thailand, Vietnam, Borneo, Sumatra, Java, Bali (Savela, 2014)	2879, 9792618, China (Qingdao)>China (Ningbo)>Korea (Busan), May-27-2023	2018
<b>Notodontidae</b>					
23	<i>Euhampsonia serratifera</i>	1 (1/0)	Thailand, Myanmar, Vietnam, China (Savela, 2014)	3305, 9784324, China (Ningbo)>China (Shanghai)>Korea (Busan), Jul-27-2023	2018, 2019, 2021, 2022
<b>Psychidae</b>					
24	<i>Eumeta variegatus</i>	1 (1/0)	Borneo, Celebes, Sumatra, Java, New Guinea, Amboina, Moluccas, Philippines, Ceylon, India, Indochina, Taiwan, E.China, Japan (Savela, 2014)	2961, 9396799, Singapore (Unknown)>non-stop>Korea (Yeosu), Jun-6-2023	
<b>Zygaenidae</b>					
25	<i>Histia flabellicornis</i>	1 (1/0)	India, Nepal, Myanmar, Thailand, Malaysia, China, Taiwan, Japan (Savela, 2014)	3065, 9900849, China (Unknown)>non-stop>Korea (Yeosu), Jun-18-2023	
<b>25 species,</b>		<b>39 individuals</b>	-	-	<b>Three Regulated species</b>
<b>18 families,</b>		<b>(32/7)</b>			
<b>six orders</b>					

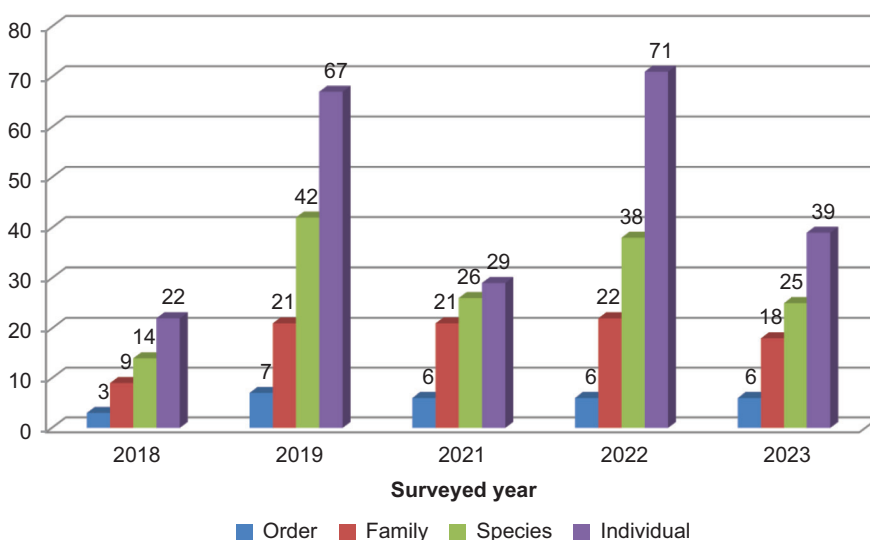


**Fig. 1.** Species composition of not-distributed species in Korea detected from international vessels in 2023.

*Cyclopeltaparva* (Dinidoridae, Hemiptera, 2 individs.), *Oryctes rhinoceros* (Scarabaeidae, Coleoptera, 1 individ.), *Formica cunicularia* (Formicidae, Hymenoptera, 3 individs.), *Oecophylla smaragdina* (Formicidae, Hymenoptera, 2 individs.), *Polyphagozerra coffeae* (Cossidae, Lepidoptera, 1 individ.), *Eumorphobotys eumorphalis* (Crambidae, Lepidoptera, 2 individs.), *Lemyra rhodophilodes* (Erebidae, Lepidoptera, 2 individs.), *Problepsis phoebearia* (Geometridae, Lepidoptera, 1 individ.), *Euhampsonia serratifera* (Notodontidae, Lepidoptera, 1 individ.) were detected again in 2023, two species (*Chloroclystis pyrrholopa* (Geometridae, Lepidoptera, 1 individ.), *E. serratifera*) in 2021, four species (*Chrysoperla suzukii* (Chrysopidae, Neuroptera, 4 individs.), *F. cunicularia*, *E. eumorphalis*, *E. serratifera*) in 2019, and three species (*L. rhodophilodes*, *Parasa pastoralis* (Limacodidae, Lepidoptera, 1 individ.), *E. serratifera*) in 2018 (Table 1). The likelihood of



**Fig. 2.** Photographs of regulated species listed by the Animal and Plant Quarantine Agency, detected on international vessels entering Korea. (A) *Oryctes rhinoceros* (Scarabaeidae, Coleoptera); (B) *Oecophylla smaragdina* (Formicidae, Hymenoptera); (C) *Solenopsis invicta* (Formicidae, Hymenoptera) (Scale bar = 5 mm).



**Fig. 3.** Comparison of species composition among non-distributed species in Korea, detected on international vessels over the past five years.

colonization by alien species increases with greater inflow amounts or frequencies (Lockwood *et al.*, 2005, Johnston *et al.*, 2009). Therefore, for species that are repeatedly hitchhiking or continuously detected, intensive surveys such as targeted quarantine inspections at the vessels' port of entry or continuous monitoring around the port where the vessel is anchored are necessary. This study provides biological information including taxonomic details, original distribution, and detection data on non-native species in Korea detected in 2023 to establish rapid response plans.

### Author Contributions

Tae Hwa Kang: Project manager, project design and conduct, data analysis (DNA barcoding and morphological examination), manuscript draft and editing; Jae Ung Seol: Assistant for project, sample management; Deuk-Soo Choi: Project design, data analysis (morphological examination), manuscript editing.

### Conflicts of Interest

The authors declare that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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