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Alien hitchhiker insect species detected from the international vessels entering into Korea in 2021

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We monitored the hitchhiker insect pests from the international vessels entering into Korea in 2021. As a result, total of 581 individuals were detected by the survey based on visual inspection with naked eye. Among them, 500 individuals were identified as 244 species of 65 families under 11 orders through the integrative taxonomic method with DNA barcoding and morphological reexamination, but the remaining 81 individuals were classified as only to the family level. Of the 244 species identified, 26 species were determined to be not-distributed species in Korea (two Orthoptera, two Hemiptera, one Megaloptera, five Coleoptera, three Hymenoptera, and 13 Lepidoptera). Among them, two species, *Sagra femorata* (Chrysomelidae, Coleoptera) and *Dendrolimus punctatus* (Lasiocampidae, Lepidoptera), were discovered as 'Regulated species' listed by Animal and Plant Quarantine Agency, South Korea. Therefore, we reported on the 26 not-distributed species in Korea and provided inanimate pathway information such as navigation routes on the vessels hitchhiking the species, state of the samples at the time of detection, identification results and original distribution for the detailed monitoring and the risk analysis on the species.

Keywords: hitchhiker insect pest, international vessel, monitoring, not-distributed species in Korea, quarantine inspection

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Introduction

Cases of hitchhiker organisms that have temporary associations with artificial structures or objects are increasing with the increase in international trade (Armstrong and Ball, 2005; Hulme, 2009; Toy and Newfield, 2010). Due to the increase in invasion cases of alien organisms, the Convention on Biological Diversity (CBD) adopted the matters related to invasive organisms in COP decision VI/23, and in particular, proposed a plan for the risk analysis of invasive organisms (SCBD, 2006). In addition, the International Plant Protection Convention (IPPC) recognized the risk factors of hitchhiker pests due to the increase in international trade, and established the Sea Container Task Force Team for inspection methods and risk management on hitchhiker organisms in 2018 (IPPC, 2020). The countermeasures of the world-famous hitchhiker organisms, such as *Solenopsis invicta* and *Lymantria dispar*, were provided through in-depth analysis on the inanimate pathway of hitchhiker organisms. In the case of the red fire ant (*S. invicta*), an analysis of the chronological invasion and spread pathway was performed (Ascunce *et al*., 2011). In the case of the gypsy moth (*L. dispar*) which lays egg masses on artificial structures such as sea container, a population genetic analysis was carried out at the global level (Wu *et al*., 2015).

In Korea, there are various problems of hitchhiker insects such as detection of *Solenopsis invicta*, invasion and spread of *Vespa velutina*, and mass occurrence of *Melanoplus differentialis* around ports were occurred (Choi *et al*., 2012b; Lyu and Lee, 2017; Kang *et al*., 2022). As the biological problem of hitchhiker organisms expands to social problems such as mass occurrence in urban areas, the monitoring on hitchhiker pests was actively conducted in Korea (YNA, 2018; 2022). Especially, the frequency of detection of not-distributed hitchhiker insect species in Korea showed as increasing from 14 species in 2018 to 42 species in 2019 (Kang *et al*., 2020; 2021).

Table 1. Summary on data sheet of the alien hitchhiker insect species detected from the international vessels entering into Korea.

No.	Scientific name	No. of detected individuals (Live/Dead)	Distribution	Navigation route and Collecting date (Sample no.; Outport > Transit > Destination; Collecting date)	Remarks
	Order Orthoptera				
	Family Acrididae				
1	*Chondracris rosea*	1(1/0)	India, China, Indochina, Malaysia, Taiwan	1483; China > nonstop > Korea; 27. viii. 2021	
	Family Tettigoniidae				
2	*Mecopoda elongata*	1(1/0)	India, Sri Lanka, Indo-China, China, Taiwan, Malesia through to Melanesia	1657; Shanghai, China > Qingdao, China > Busan, Korea; 13. viii. 2018	
	Order Hemiptera				
	Family Reduviidae				
3	*Epidaus famulus*	1(1/0)	Burma, China, Malaya, Sumatra, Vietnam	1261; China > nonstop > Busan, Korea; 20. v. 2021	
	Family Scutelleridae				
4	*Poecilocoris druraei*	1(0/1)	Hong Kong, Taiwan, Thailand	1802; Ningbo, China > Yangshan, China > Busan, Korea; 26. vi. 2021	
	Order Megaloptera				
	Family Corydalidae				
5	*Neochauliodes meridionalis*	2(0/2)	China, Vietnam	1630; Tianjin, China > Onsan, Korea > Donghae, Korea; 3. viii. 2021 1673; Lugus Sulu, Philippines > Lianyungang, China > Okye, Korea; 7. vii. 2021	
	Order Coleoptera				
	Family Carabidae				
6	*Calathus fuscipes*	1(0/1)	Europe except for Andorra, Monaco, San Marino, Vatican City and various islands	1751; Xiamen, China > HongKong > Busan, Korea; 25. vii. 2021	
	Family Lucanidae				
7	*Odontolabis cuvera*	1(0/1)	Bhutan, China, India, Laos, Myanmar, Nepal, Thailand, Vietnam	1750; Xiamen, China > HongKong > Busan, Korea; 25. vii. 2021	
	Family Coccinellidae				
8	*Eriopis chilensis*	1(1/0)	Chile	1279; Chile > Gunsan, Korea > Gwangyang, Korea; 15. iv. 2021	
	Family Chrysomelidae				
9	*Sagra femorata*	1(0/1)	Cambodia, China, India, Java, Laos, Myanmar, Sri Lanka, Thailand, Vietnam	1798; Shanghai, China > nonstop > Busan, Korea; 25. vi. 2021	Regulated species
	Family Cerambycidae				
10	*Anoplophora horsfieldii*	1(0/1)	Thailand, Vietnam, China, Taiwan	1394; Korea > nonstop > Ulsan, Korea; 1. viii. 2021	
	Order Hymenoptera				
	Family Pompilidae				
11	*Cryptocheilus australis*	1(0/1)	Tasmania, south-eastern Australia	1350; Santai, China > nonstop > Gwangyang, Korea; 15. v. 2021	
	Family Formicidae				
12	*Atta colombica*	1(0/1)	Guatemala, Colombia, Costa Rica	1795; Nagoya, Japan > Higashiharima, Japan > Busan, Korea; 1. vii. 2021	
	Family Apidae				
13	*Eucera nigrescens*	1(1/0)	Southern Europe and east to Russia, eastern Mediterranean and further east to Turkmenistan	1306; Canal Transit, Panamas > Jangsu, China > Yeosu, Korea; 30. iv. 2021	

Table 1. Continued.

No.	Scientific name	No. of detected individuals (Live/Dead)	Distribution	Navigation route and Collecting date (Sample no.; Outport > Transit > Destination; Collecting date)	Remarks
	Order Lepidoptera				
	Family Crambidae				
14	*Palpita quadristigmalis*	1(0/1)	North America (Quebec, Ontario to Florida, west to Arizona, north to Colorado)	1704; Russia > nonstop > Pohang, Korea; 14. vi. 2021	
	Family Pyralidae				
15	*Arippara disticha*	1(1/0)	Australia	1369; China > nonstop > Ulsan, Korea; 16. vii. 2021	
	Family Nolidae				
16	*Blenina donans*	2(0/2)	India, Sri Lanka, Burma, Borneo, New Guinea, Australia, New Caledonia	1700, 1701; Australia > nonstop > Pohang, Korea; 16. vi. 2021	
17	*Gadirtha fusca*	1(1/0)	China	1461; USA > Ulsan, Korea > Incheon, Korea; 12. vii. 2021	
	Family Geometridae				
18	*Chloroclystis pyrrholopha*	1(0/1)	Australia	1345; Ulsan, Korea > nonstop > Yeosu, Korea; 10. v. 2021	
	Family Erebidae				
19	*Achaea serva*	1(0/1)	India, Sri Lanka, Myanmar, China, Borneo, Hong Kong, Java, Philippines, New Hebrides, Okinawa, western Micronesian islands, New Guinea, Australia	1579; Singapore > Vung Tau, Vietnam > Busan, Korea; 31. vii. 2021	
20	*Anomis combinans*	1(0/1)	Australia, Sri Lanka, Borneo, New Guinea, Malaysia, Timor	1699; Australia > nonstop > Pohang, Korea; 16. vi. 2021	
21	*Eudocima procus*	1(0/1)	Suriname, Colombia, Peru, Brazil, Paraguay	1300; China > nonstop > Yeosu, Korea; 27. iv. 2021	
22	*Laspeyria subrosea*	1(1/0)	Japan	1442; Jamaica > Panamas > Incheon, Korea; 2. viii. 2021	
23	*Mimophisma delunaris*	1(0/1)	Canada, USA, Mexco, Colombia, Guatemala, Paraguay, Argentina, Costa Rica	1330; China > Gunsan, Korea > Gwangyang, Korea; 8. v. 2021	
	Family Notodontidae				
24	*Euhampsonia serratifera*	2(2/0)	Thailand, Burma, Vietnam, China	1600; Ereglisi, Turkey > Freeport, USA > Donghae, Korea; 20. vii. 2021 1809; Yangshan, China > Ningbo, China > Busan, Korea; 5. vii. 2021	
	Family Lasiocampidae				
25	*Dendrolimus punctatus*	1(0/1)	China, Japan, Taiwan, Vietnam	1582; Ningbo, China > Yangshan, China > Busan, China; 28. vii. 2021	Regulated species
	Family Sphingidae				
26	*Clanis stenosema*	1(1/0)	Nias, Sumatra, Java, Borneo, Philippines	1741; Singapore > Brazil > Daesan, Korea; 15. vii. 2021	
Total	26 species, 21 families, 6 orders	29 individs.	–	–	–

Due to this increasing trend, an in-depth study on the inanimate pathway of the hitchhiker organism is required. Therefore, the goal of this study is to report the not-distributed species in Korea detected through monitoring the hitchhiker insect pests on the international vessels entering into Korea. Additionally, we provided the navigation route on the monitored international vessel, the taxonomic information such as scientific name and the original distribution, and the detection frequency of detected not-distributed species in Korea for preparing the countermeasures on the hitchhiker insect species.

Materials and Methods

Monitoring the hitchhiker insect pests on the international vessels was conducted along the passage from the bow to the stern of the vessel through visual method with naked eye. The detected hitchhiker pests were collected separately from live and dead individuals. The samples were firstly identified through comparing DNA barcode of the samples with BLAST searching Method in NCBI and Identification Engine in BOLD ver. 4 based on 2% cutoff rule (Altschul *et al*., 1990; Hebert *et al*., 2003; 2004; Ratnasingham and Hebert, 2007), and then, the morphological re-examination of the samples was carried out. Among the detected species, verification of not-distributed species in Korea was diagnosed by comparing with National Species List of Korea and Biodiversity of Korean Peninsula (NIBR, 2011; 2018; 2019). According to identification results, we reorganized the original distribution of each species examining the previous studies (Kimoto and Gressitt, 1979; Harris, 1987; Lingafelter and Hoebeke, 2002; Al-Ghazwi *et al*., 2006; Ambrose, 2006; Tasi and Rédei, 2009; Liu *et al*., 2010; Savela, 2014; Gonzalez *et al*., 2020; Ascher and Pickering, 2021; CAS, 2023; Cigliano *et al*., 2023).

Results

In the results of the analysis on 581 individuals detected from the international vessels entering into Korea, 500 individuals were identified as 244 species of 65 families under 11 orders, but 81 individuals were only classified to the family level. Among 244 species, 26 species (29 individuals) were discovered as not-distributed species in Korea (Fig. 1, Table 1). Examining the species composition of the not-distributed species in Korea, Lepidoptera was the most common with 13 species, followed by five species Coleoptera, three Hymenoptera, two Orthoptera, two Hemiptera, and one Megaloptera. Of these species, two, *Sagra femorata* (Chrysomelidae, Coleoptera) and *Dendrolimus punctatus* (Lasiocampidae, Lepidoptera), were identified as species listed as the regulated pests in Animal and Plant Quarantine Agency, South Korea (Figs. 1J, 2M; Table 1) (QIA, 2013). Additionally, following 10 species (11 individuals) were detected alive: *Chondracris rosea* (Acrididae, Orthoptera), *Mecopoda elongata* (Tettigoniidae, Orthoptera), *Epidaus famulus* (Reduviidae, Hemiptera), *Eriopis chilensis* (Coccinelidae, Coleoptera), *Eucera nigrescens* (Apidae, Hymenoptera), *Arippara disticha* (Pyralidae, Lepidoptera), *Gadirtha fusca* (Nolidae, Lepidoptera), *Laspeyria subrosea* (Erebidae, Lepidoptera), *Euhampsonia serratifera* (Notodontidae, Lepidoptera), and *Clanis stenosema* (Sphingidae, Lepidoptera). And following three species (each with two individuals) were detected multiple times: *Neochauliodes meridionalis* (Corydalidae, Megaloptera), *Blenina donans* (Nolidae, Lepidoptera), and *E. serratifera*.

As a result of comparison with previously reported not-distributed hitchhiker insect pests in Korea, four species were detected in 2018 (*Chondracris rosea*, *Neochauliodes meridionalis*, *Arippara disticha* and *Euhampsonia serratifera* (Kang *et al*., 2020)), and three species were detected in 2019 (*Palpita quadristigmalis* (Crambidae, Lepidoptera), *A. disticha* and *E. serratifera* (Kang *et al*., 2021)). Two species, *A. disticha* and *E. serratifera*, were continuously detected in 2018 and 2019 (Kang *et al*., 2020; 2021). Therefore, it was considered that these two species are highly likely to invade through hitchhiking on the international vessels.

Discussion

In general, it was known that the possibility of colonization of alien species increases as the inflow amount or frequency increases (Lockwood *et al*., 2005; Johnston *et al*., 2009). In the case of hitchhiker alien species, the possibility of establishment might be high when the frequency of entry into the same route is low but the number of individuals in the single entry is large (Toy and Newfield, 2010). Examining the patterns of multiple detections in the results of this study, it was possible to confirm two cases: 1) two or more individuals in a species were detected in the current year; 2) a species was continuously detected from previous years. Comparing the departure port of monitored vessel with the original distribution of five species detected multiple times (*Neochauliodes meridionalis*, *Palpita quadristigmalis*, *Arippara disticha*, *Blenina donans*, and *Euhampsonia serratifera*), for three species (*N. meridionalis*, *B. donans* and *E. serratifera*), it was confirmed that the original distribution included the port of departure of the monitored vessel, but the other two species were not included (Table 1). In view of these results, it might be necessary to closely examine the recent voyage route of the vessel. In the case of the two species, *P. quad-*

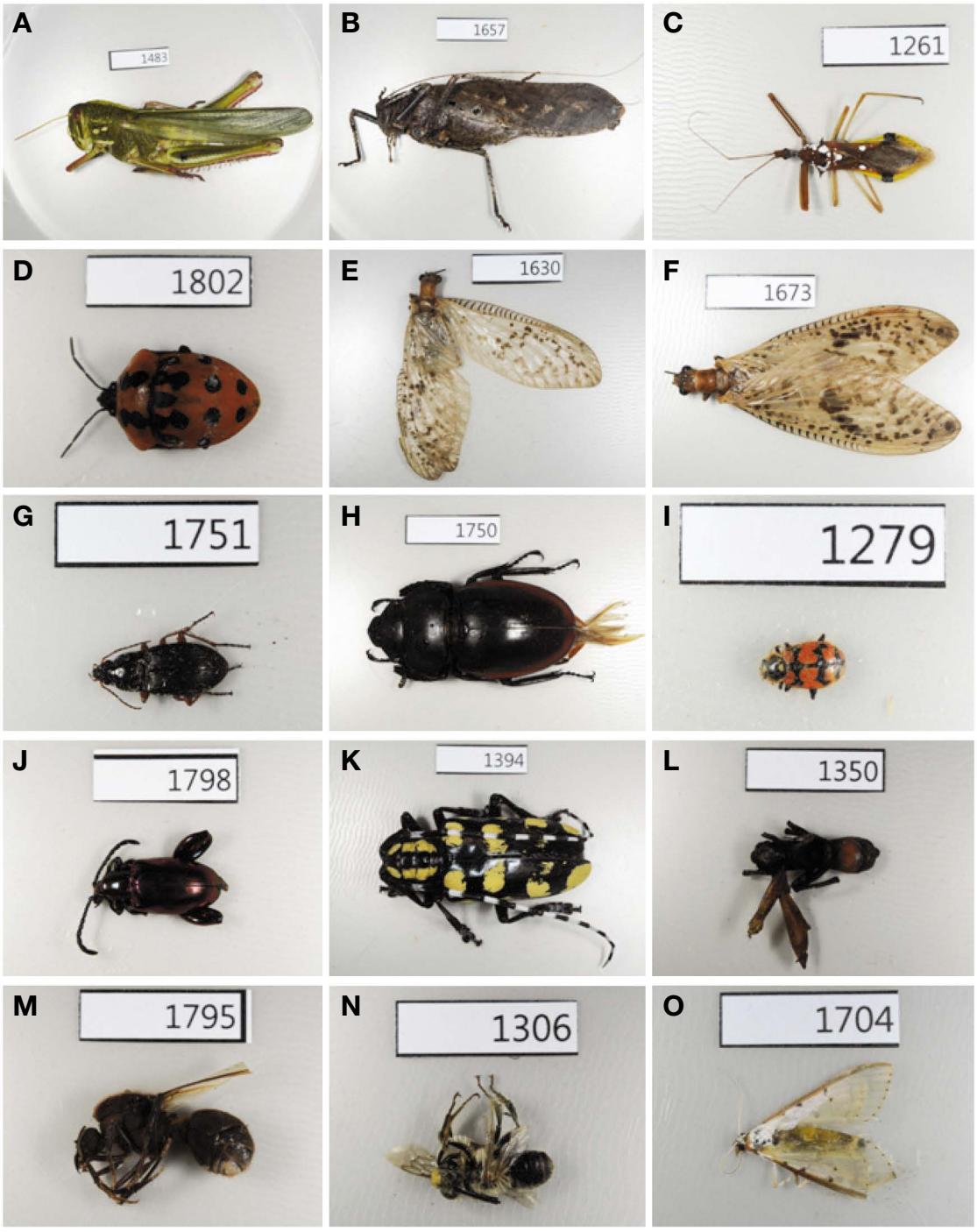

Fig. 1. Body photos on detected individuals of the alien hitchhiking insect species from the international vessels. A. *Chondracris rosea* (Acrididae, Orthoptera); B. *Mecopoda elongata* (Tettigoniidae, ditto); C. *Epidaus famulus* (Reduviidae, Hemiptera); D. *Poecilocoris druraei* (Scutelleridae, ditto); E, F. *Neochauliodes meridionalis* (Corydalidae, Megaloptera); G. *Calathus fuscipes* (Carabidae, Coleoptera); H. *Odontolabis cuvera* (Lucanidae, ditto); I. *Eriopis chilensis* (Coccinellidae, ditto); J. *Sagra femorata* (Chrysomelidae, ditto); K. *Anoplophora horsfieldii* (Cerambycidae, ditto); L. *Cryptocheilus australis* (Pompilidae, Hymenoptera); M. *Atta colombica* (Formicidae, ditto); N. *Eucera nigrescens* (Apidae, ditto); O. *Palpita quadristigmalis* (Crambidae, Lepidoptera).

ristigmalis and *A. disticha*, that the port of departure of the monitored vessel was not included in the original distribution, it was possible that they might settle in the country just before entering Korea or final entry port area.

During the past 20 years, it was known that about eight alien insect species (*Ophraella communa*, *Lycorma deli-*

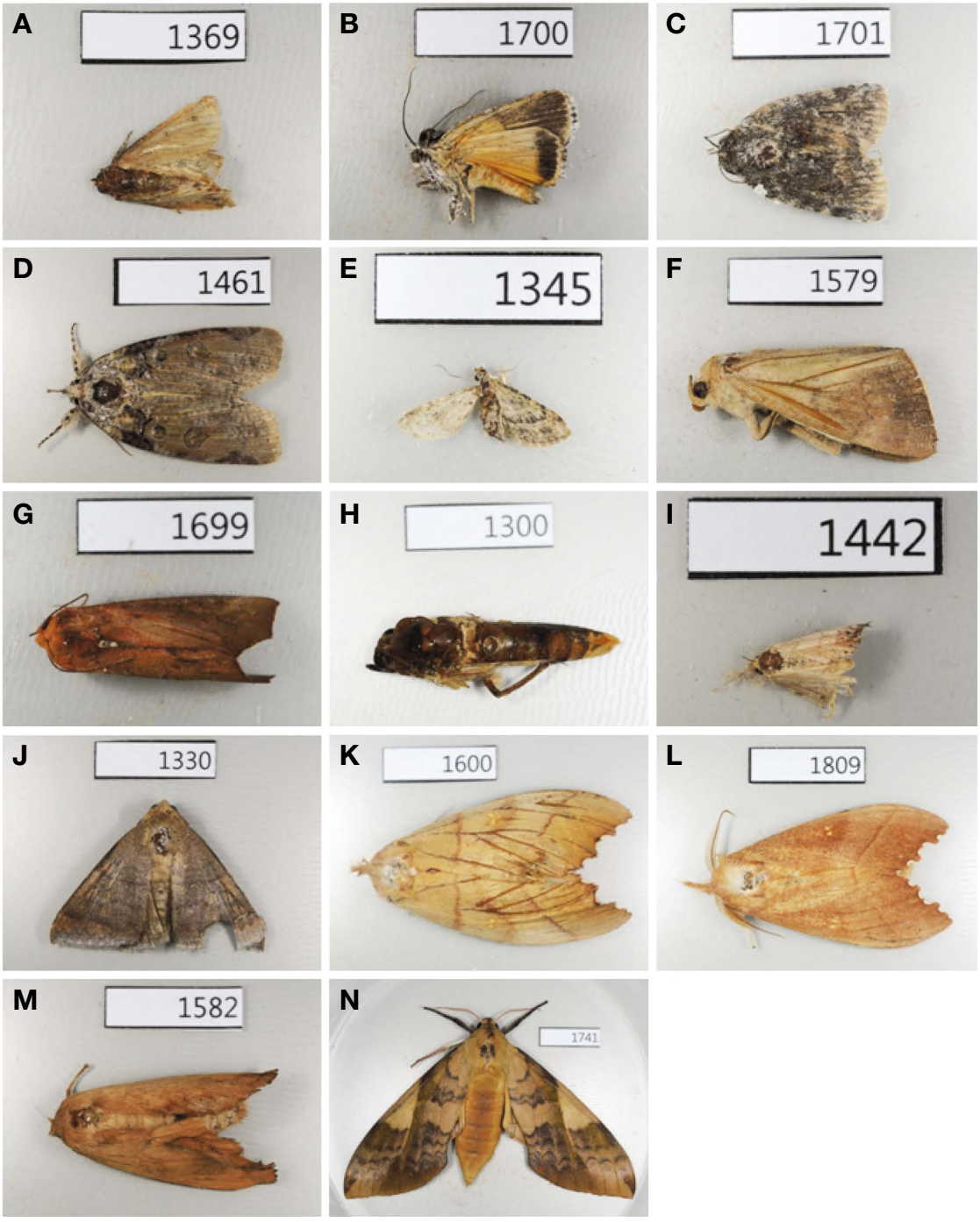

Fig. 2. Body photos on detected individuals of the alien hitchhiking insect species from the international vessels. A. *Arippara disticha* (Pyralidae, Lepidoptera); B, C. *Blenina donans* (Nolidae, ditto); D. *Gadirtha fusca* (Nolidae, ditto); E. *Chloroclystis pyrrholopha* (Geometridae, ditto); F. *Achaea serva* (Erebidae, ditto); G. *Anomis combinans* (Erebidae, ditto); H. *Eudocima procus* (Erebidae, ditto); I. *Laspeyria subrosea* (Erebidae, ditto); J. *Mimophisma delunaris* (Erebidae, ditto); K, L. *Euhampsonia serratifera* (Notodontidae, ditto); M. *Dendrolimus punctatus* (Lasiocampidae, ditto); N. *Clanis stenosema* (Sphingidae, ditto).

catula, *Ricania sublimata*, *Vespa velutina*, *Leptoglossus occidentalis*, *Metcalfa pruinosa*, *Brachymna tenuis*, and *Melanoplus differentialis*) invaded Korea through various routes including inanimate pathways (Sohn *et al*., 2002; Park *et al*., 2009; Choi *et al*., 2012a; 2012b; Yoon *et al*., 2012; Kim and Kil, 2014; Ahn *et al*., 2020; Kang *et al*.,

2022). In addition, red fire ants were detected in the inland of the Korean Peninsula, although the establishment of the species was not reported in Korea (Lyu and Lee, 2017). It was inferred or confirmed that the invasion of alien species might be due to increase international trade (Sohn *et al*., 2002; Choi *et al*., 2012a; 2012b; Yoon *et al*., 2012; Kim and Kil, 2014; Kang *et al*., 2022). Accordingly, for the multiple detection of not-distributed species in Korea confirmed in this study, it might be necessary to monitor the invasion situation of the species focusing on the entry port area of the vessels that the species were detected. After then, the alien species detected through the monitoring should be analyzed for possible ripple effects on the local ecosystem through risk assessment. CBD and IPPC recommended the risk analysis on invasive species (SCBD, 2006; IPPC, 2020). Therefore, it might be necessary to introduce a sustainable risk assessment method centered on related institutes of national agency in Korea. The introduction of such a risk assessment is expected to reduce the frequency of invasion by alien species, and finally might reduce future threats to the ecosystem of the Korean Peninsula.

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