



Article Host Range Expansion of Nest-Parasitic Moths *Pyralis regalis* and *Hypsopygia mauritialis* in Social Wasp Nests: New Findings and Implications for Biological Control

Young-Min Shin¹, Heung Sik Lee², Il-Kwon Kim¹, Chang-Jun Kim³ and Moon Bo Choi^{4,5,*}

- ¹ Division of Forest Biodiversity, Korea National Arboretum, Pocheon 11816, Republic of Korea; ymshin89@korea.kr (Y.-M.S.); ilkwons91@korea.kr (I.-K.K.)
- ² Center for Plant Quarantine Technology, Animal and Plant Quarantine Agency, Gimcheon 39660, Republic of Korea; lhsgo@korea.kr
- ³ Division of Gardens and Education, Korea National Arboretum, Pocheon 11816, Republic of Korea; changjunkim@korea.kr
- ⁴ Institute of Plant Medicine, Kyungpook National University, Daegu 41566, Republic of Korea
- ⁵ Department of R&D, Wild Beei, Chilgok 39885, Republic of Korea
- * Correspondence: kosinchoi@hanmail.net; Tel.: +82-53-950-5762

Abstract: Parasitic moths are common in social wasp (Hymenoptera) nests, attacking many species of Polistinae and a few species of Vespinae. In the Republic of Korea, two moth species are known to parasitize the brood of *Polistes rothneyi koreanus: Pyralis regalis* (Pyralidae) and *Anatrachyntis japonica* (Cosmopterigidae). Although previously reported elsewhere, a novel case of parasitization was recently documented in the Republic of Korea, in which *Hypsopygia mauritialis* (Pyralidae) was identified in the nests of social wasps. *Pyralis regalis* is the most common parasitic moth in the Republic of Korea, feeding on the nests of 11 species of social wasps, mostly the Korean *Vespa* species. To that list of hosts, we add a species of *Dolichovespula* and two species of *Polistes*. Parasitism of *Vespa velutina nigrithorax*, an invasive alien hornet, by both *P. regalis* and *H. mauritialis*, was observed for the first time. However, their potential to control invasive alien hornets is expected to be low. This study provides new insights into the diversity of nest-parasitic moths in social wasp nests and their hosts in the Republic of Korea, and highlights the potential for these moths to impact pest populations.

Keywords: Vespidae; parasitoid moth; Hypsopygia; Vespa velutina; Pyralidae; Cosmopterigidae

1. Introduction

Vespidae harbor numerous parasites, including endoparasites and parasitoids. Adults wasps are parasitized by twisted-winged insects (Stylopidae: Strepsiptera) and nematode worms (Mermithidae: Nematoda) [1], and colonies are attacked by the larvae of various species of moths, including *Pyralis* sp. (Pyralidae), *Hypsopygia* spp. (Pyralidae), *Aphomia* sp. (Pyralidae), *Chalcoela* spp. (Crambidae), *Anatrachyntis* spp. (Cosmopterigidae), *Tinea* spp. (Tineidae), *Antipolistes* sp. (Tineidae), *Taeniodictys* sp. (Lyonetiidae), and *Athrips* sp. (Gelechiidae) [2–12]. Most of these moths parasitize Polistinae (*Polistes* spp. and *Belonogaster* spp.), but some species of Pyralidae occur in the nests of Vespinae as well [1]. Notably, *Pyralis regalis* (Denis and Schiffermüller, 1775) and *Hypsopygia mauritialis* (Boisduval, 1833) are known to parasitize *Vespa* spp. [1,13], while *Aphomia sociella* (Linnaeus, 1758) is parasitic in the nests of both *Vespula* spp. and *Dolichovespula* spp. [14,15].

Some parasitic moths facultatively feed on their host's embryos. Others burrow through nest fibers, feeding on the developing wasp larvae and pupae in the cells, ultimately killing them. In addition, moth larvae obstruct the use of the nest by filling each cell with silk-like webbing, making it challenging for adult wasps to navigate the nest. Moth overwintering is typically accomplished in the abandoned nest, after the social wasp colony



Citation: Shin, Y.-M.; Lee, H.S.; Kim, I.-K.; Kim, C.-J.; Choi, M.B. Host Range Expansion of Nest-Parasitic Moths *Pyralis regalis* and *Hypsopygia mauritialis* in Social Wasp Nests: New Findings and Implications for Biological Control. *Diversity* **2023**, *15*, 789. https://doi.org/10.3390/ d15060789

Academic Editors: Simone Lioy, Xesús Feás and Luc Legal

Received: 15 May 2023 Revised: 14 June 2023 Accepted: 16 June 2023 Published: 19 June 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). has completed its life cycle, with emergence usually taking place in early spring of the following year [6]. These moths are conspicuous natural enemies, weakening or disrupting wasp colonies [1,13,16]. Despite the commonness and importance of these moth-wasp interactions, studies on parasitoid moth hosts, development, and ecology are scarce.

Thirty species of social wasps have been recorded in the Republic of Korea [17], including the recently introduced hornet, *Vespa velutina nigrithorax* (du Buysson, 1905), which is now spreading [18], causing not only sting accidents in rural, forest, and urban areas, but also disrupting honeybees in apiaries, which has a significant economic impact [19–21]. Therefore, interest in biological control through natural enemies, as well as physico-chemical control, is increasing [22]; unfortunately, there is limited previous research on these topics. In the Republic of Korea, the only known nest-parasitic moths from social wasp nests are *P. regalis* and *Anatrachyntis japonica* (Kuroko, 1982), both which attack the nests of *Polistes jadwigae* (Dalla Torre, 1904) (=*P. rothneyi*, Cameron, 1900) [23]. In this study we identified moth species using morphological characters and DNA barcodes of the *Hypsopygia* species, which were newly recorded in the nests of social wasps. Our results are based on an eight-year study of parasitoid moths in Korea.

2. Materials and Methods

2.1. Sample Collection

We collected social wasp nests from 2014 to 2023. The nests underwent scrutiny, and any cells exhibiting evidence of silk bundles attributable to parasitic moths, or those harboring moth larvae and adults, during either indoor or outdoor storage or during nest dissection were recorded separately. For nests with severe infections, a breeding net $(60 \times 38 \times 40 \text{ cm})$ (Manchun, Seoul, Republic of Korea) was utilized, and monitoring was conducted until all moths emerged. Pertinent information such as the host wasp species, collection site, date of nest collection, date of moth emergence, and the total count of moths was meticulously documented for each nest (Table 1 and Supplementary Table S1).

Nest No.	Hosts (Social Wasp)	⁺ Collected Location of Host Nest	Nest Collecting Date	Date of Moth Emergence	Stage of Development	Number of Emergence
1. Pyralis re	egalis					
1	Dolichovespula kuami	Pocheon	5 Jun. 2018	5 Jun. 2018	А	2
2	D. kuami	Jeongeup	17 Aug. 2018	23–29 Aug. 2018	А	16
3	D. kuami	Andong	11 Oct. 2020	12 Oct. 2020	L	3
4	Vespa crabro flavofasciata	Masan	15 Dec. 2017	3–22 May. 2018	А	47
5	V. crabro flavofasciata	Uljin	28 Sep. 2020	3 Oct. 2020	L	4
6	V. simillima simillima	Andong	30 Aug. 2020	16 Sep. 2020	L	6
7	V. simillima	Andong	15 Oct. 2021	19 Oct. 2021	L	14
8	V. velutina nigrithorax	Gurye	5 Nov. 2018	11 Nov. 2018	L	7
9	V. velutina nigrithorax	Andong	28 Nov. 2018	11 Feb.–6 Mar. 2019	А	24
					L	19
10	V. velutina nigrithorax	Andong	13 Nov. 2019	16 Nov.2019	L	8
11	V. velutina nigrithorax	Andong	3 Aug. 2021	3 Aug. 2021	А	7
					L	36
12	V. velutina nigrithorax	Andong	9 Dec. 2021	15 Feb.–28 Mar. 2022	А	8
13	V. ducalis		11 Oct. 2019	13 Oct. 2019	L	2
14	V. analis parallela	Andong	1 Oct. 2021	1 Oct. 2021	L	6
15	V. dybowskii	Andong	25 Sep. 2019	25 Sep. 2019	L	4
16	V. mandarinia	Yecheon	20 Sep. 2019	20 Sep. 2019	L	6

Table 1. Parasitic moths developed in the nests of social wasps (host) from 2014 to 2023.

Nest No.	Hosts (Social Wasp)	⁺ Collected Location of Host Nest	Nest Collecting Date	Date of Moth Emergence	Stage of Development	Number of Emergence			
17	V. mandarinia	Andong	27 Oct. 2022	27 Oct. 2022	L	2			
18	V. mandarinia	Uiseong	20 Oct. 2022	22 Jan.–18 Mar. 2023	А	22			
					L	45			
19	V. mandarinia	Uiseong	20 Oct. 2022	2 Feb3 Mar. 2023	А	39			
					L	52			
20	Polistes rothneyi koreanus	Yecheon	23 Aug. 2021	25 Aug. 2021	А	4			
21	P. rothneyi koreanus	Yecheon	30 Jul. 2021	7 Aug. 2021	L	2			
22 #	P. rothneyi koreanus	Gunwi	2 Sep. 2017	2 Sep. 2017	А	8			
23	P. rothneyi koreanus	Gunwi	16 Dec. 2014	9–22 Feb. 2015	А	4			
24	P. rothneyi koreanus	Gunwi	28 Sep. 2016	20 Jan.–23 Feb. 2017	А	11			
					L	20			
25	P. rothneyi koreanus	Gunwi	1 Oct. 2018	22 Jan.–2 Mar. 2019	А	7			
					L	5			
26	P. yokahamae	Yeongcheon	3 Oct. 2021	3 Oct. 2021	L	2			
27	P. nipponensis	Seongju	28 Oct. 2022	12 Feb. 2023	L	1			
2. Anatrachyntis japonica									
28	P. rothneyi koreanus	Gunwi	6 Dec. 2014	20 Feb. 2015	А	15			
29	P. rothneyi koreanus	Gunwi	2 Sep. 2017	2 Sep. 2017	Α	18			
30	P. rothneyi koreanus	Andong	22 Jun. 2021	15 Jul. 2021	А	2			
31	P. rothneyi koreanus	Yecheon	20 Jul. 2021	3 Aug. 2021	А	41			
32	P. rothneyi koreanus	Andong	24 Jul. 2021	24 Jul. 2021	А	8			
33	V. crabro flavofasciata	Gunwi	16 Sep. 2015	16 Sep. 2015	А	3			
3. Hypsopygia mauritialis									
34	P. rothneyi koreanus	Gurye	10 Sep. 2021	23 Jan. 2022	А	13			
35	P. rothneyi koreanus	Jeonju	31 Dec. 2021	2 Jan. 2022	А	32			
36	P. rothneyi koreanus	Seongju	28 Oct. 2022	16 Jan. 2023	А	5			
37	V. velutina nigrithorax	Jinju	22 Jan. 2021	30 Jan.–18 Mar. 2021	А	11			
					L	4			
38	V. velutina nigrithorax	Jinju	11 Aug. 2022	11 Aug. 2022	L	8			
				22 Aug. 2022	А	6			

Table 1. Cont.

22[#] is the same nest as 29.[†] See Supplementary Table S1 for locations where social wasps were collected.

2.2. Identification

Based on a list of moths previously recorded by Jeong et al. [23], the moths in this study were identified based on studies by Lee and Bae [24], and Yoon and Byun [25], and the larvae were identified based on Heo [26].

The *Hypsopygia* sp., an undiscovered moth in the Republic of Korea, was identified based on its external morphology, genitalia, and DNA barcodes. Larvae were inferred based on the adult species in the nest and identified using a description by Yamane et al. [16].

The male and female genitalia were dissected and mounted with an euparal solution, as described previously [27]. Images were captured using a DFC 495 digital camera (Leica, Wetzlar, Germany) attached to a LEICA M205C (Leica) and a Dhyana 95 scientific CMOS camera (Tucsen, Fuzhou, China) attached to a Leica DM 3000 LED optical microscope (Leica).

Genomic DNA from 13 Korean specimens of *Hypsopygia* sp., 6 specimens from Gurye, and 7 specimens from Jeonju were extracted using a Genomic Cell/Tissue Spin Mini Kit (Qiagen, Inc., Hilden, Germany) according to the manufacturer's protocol. The DNA

barcodes were amplified using the primers LepF1, LepR1 [28], MLepF1, MLepR1 [29]. The PCR conditions for amplification followed the manufacturer's protocol (Platinum Taq, Invitrogen, Carlsbad City, CA, USA). The amplicons were purified using the QIAquick[®] PCR purification kit (QIAGEN, Inc., Hilden, Germany) and directly sequenced at Macrogen (Seoul, Republic of Korea). The contigs were assembled using Geneious 11 (Biomatters, Auckland, New Zealand).

We also used the data from 45 COI sequences of 11 species registered in BOLD SYSTEMS and NCBI. In total, 11 species with 58 COI sequences, including outgroups, were used for data analysis. Sequence alignments were performed using MEGA 11 [30], and uncertain anterior and posterior regions were removed. Neighbor-joining analysis was performed, and pairwise distances were calculated using MEGA 11 [30] based on the Kimura-2-Parameter (K2P) model. Bootstrap support values for each node were evaluated using 1000 replicates. As an outgroup, we selected *P. regalis*, which belongs to the sister group [31] of the Tribe Pyralini.

The specimens used in this study have been deposited in the KNAE (Entomological Collection, Korea National Arboretum, Pocheon). The abbreviations used in this study are as follows: TD, type depository; TL, type locality; Synonym, (=); BMNH, Natural History Museum, London, UK.

3. Results

3.1. Systematic Accounts

Family Pyralidae Latreille, 1809 [32] Subfamily Pyralinae Latreille, 1809 [32] Genus Hypsopygia Hübner, 1825 [33] Hypsopygia mauritialis (Boisduval, 1833) [34] Asopia mauritialis Boisduval, 1833:119. TL: Mauritius; TD: BMNH. [34] Pyralis lucillalis Walker, 1859: 268 [35] Pyralis regalis Walker, 1866: 1241 [36] Pyralis ducalis Walker, 1866: 1242 [36] Endotricha crobulus Lucas, 1891: 305 [37] Hypsopygia laticilialis Ragonot, 1891: 28 [38] Hypsopygia sanguinalis Warren, 1897: 125 [39] Hypsopygia atralis Caradja, 1932: 121 [40] Hypsopygia pfeifferi Amsel, 1954: 310 [41]

Adult (Figure 1A,B): Wingspan 14–21 mm, head yellow on frons, vertex with yellow scales. Male antenna 4/5 of forewing length, yellow mixed with reddish purple, and ciliate. Female antenna broken. Proboscis well-developed. Thorax reddish purple. Abdomen reddish purple, with lightly scattered black scales. Forewing ground color pale reddish purple, lightly scattered with blackish purple scales; costal and outer margin blackish purple. Antemedial line arising from a yellow costal patch, pale yellow, and curved. Postmedial line narrow and rather indistinct. Costa between antemedial and postmedial line with several (4–6) yellow minute spots and blackish purple discocellular spots. Cilia bright yellow. Hindwing ground color concolorous with forewing; outer margin blackish-purple. Antemedial and post-medial yellow lines quite indistinct and sinuate, surrounded by dark purple scales. Cilia as bright yellow as the forewing.



Figure 1. *Hypsopygia mauritialis.* (**A**) Adult male; (**B**) adult female; (**C**) male genitalia (slide no. KNAEYM181); (**D**) female genitalia (slide no. KNAEYM182); (**E**) detail of signum. <Scale bar: 1 mm>.

Male genitalia (Figure 1C): Uncus dorsally stumpy; gnathos weakly sclerotized, slightly hooked distally; valva rather long and pilose; saccus long and tapered; juxta weakly sclerotized; phallus weakly sclerotized, rather long, approximately as long as valva; cornutus absent.

Female genitalia (Figure 1D,E): Apophyses thin and long, posterior apophyses 1.5 times longer than the anterior apophyses. Antrum membranous, long, and cylindrical with sclerotized colliculum. Ductus bursae long with ductus seminalis. Middle part wide and weakly sclerotized. Corpus bursae ovate with small and sclerotized signum.

Material examined: 1°19(genitalia slide no. KNAEYM281, 282), 79(DNA barcode), 7 9169(identification by external characters); Jeonju, Jeollabuk-do, 1. I. 2022. Coll. H.S. Lee; 3° (genitalia slide no. KNAEYM283), 1°59(DNA barcode), 3° 19(identification by external characters), Gurye, Jeollanam-do, 23. I. 2022. Coll. M.B. Choi; 4° 19(identification by external characters), Seongju, Gyeongsangbuk-do, 16. I. 2023. Coll. M.B. Choi; 6° 59(identification by external characters), Jinju, Gyeongsangnam-do, 30. i—18. iii 2021. Coll. J.H. Kim; 5° 19(identification by external characters), Jinju, Gyeongsangnam-do, 22 viii 2022. Coll. J.H. Kim.

Distribution: the Republic of Korea (new record), Japan, Taiwan, China, Iran, Nepal, India, Australia, Hawaii, Africa, Madagascar, and Mauritius.

3.2. DNA Barcode

The sequence was uploaded to NCBI (accession numbers: OQ579040–OQ579052). The DNA barcode obtained in this study indicated 100% genetic similarity to that of *H. mauritialis* (accession no. KX860326) (Figure 2). Molecular analyses revealed that all species were strongly supported with high bootstrap values as a single lineage on neighborjoining trees. The maximum intraspecific variation in *H. mauritialis* was 0.008%, and the interspecific pairwise K2P distances were 0.069–0.058% from the most similar species, *H. aflavmaculata* (Shaffer, Nielsen and Horak, 1996) in the COI region (Figure 2).



Figure 2. Neighbor-joining tree of the genus *Hypsopygia*. The divergence was calculated using the Kimura 2-parameter model on the basis of 280–658 bp COI sequences. Bootstrap values below 50 are not shown. The sequences of the *P. regalis*, which includes Pyralini, were used as an outgroup.

3.3. New Host Records for Nest-Parasitic Moths

Nest-parasitic moths occurring in the nests of social wasps in the Republic of Korea consist of three species within three genera and two families (Table 1). Eleven wasp species are known as the hosts of *P. regalis*; of them, seven species are in *Vespa (V. crabro flavofasciata* (Cameron, 1903), *V. simillima simillima* (Smith, 1868) (Figure 3B), *V. velutina nigrithorax, V. ducalis* (Jordan, 1922), *V. analis parallela* (André, 1884) (Figure 3A), *V. dybowskii* (André, 1884) (Figure 3D), and *V. mandarinia* (Smith, 1852) (Figure 3C), one species is in *Dolichovespula* (*D. kuami* Kim et Yoon, 1996), and three species are in *Polistes (P. rothneyi koreanus* (van der Vecht, 1968) (Figure 4A–C), *P. yokahamae* (Rodoszkowski, 1887), and *P. nipponensis* (Pérez, 1905).

The hosts of *A. japonica* were two species in two genera: *V. crabro flavofasciata* and *P. rothneyi koreanus* (Figure 4D–F). In some cases, *P. regalis* and *A. japonica* coexisted in one nest of *P. rothneyi koreanus* (Nest 22 (=29) in Table 1). *H. mauritialis,* first recorded in the Republic of Korea, appeared to have two host species within two genera (*P. rothneyi koreanus* (Figure 5) and *V. velutina nigrithorax* (Figure 6)).



Figure 3. A nest-parasitic moth, *P. regalis* (arrow), appeared in the nests of the *Vespa* species in the Republic of Korea. (**A**) Traces of silk bundles generated by *P. regalis* in the nest of *V. analis parallela;* (**B**) larvae of *P. regalis* developed from the nest of *V. simillima simillima;* (**C**) *P. regalis* adults emerged from the nest of *V. mandarinia;* (**D**) larvae of *P. regalis* developed in the nest of *V. dybowskii.*



Figure 4. Nest-parasitic moths from the nests of *P. rothneyi koreanus*. (**A**,**B**) Adult (**A**) and larvae (**B**) of *P. regalis* occurred in the nests; (**C**) excreta filled in most cells of the nest by *P. regalis* larvae feeding inside (28 September, Nest 24); (**D**) adult of *A. japonica* emerging from nest; (**E**) entire nest infected by *A. japonica*; (**F**) holes (red circle) made by *A. japonica* larvae feeding through the nest.



Figure 5. *H. mauritialis* from nests of *P. rothneyi koreanus*. (**A**) Entire nest infested by *H. mauritialis;* (**B**) *H. mauritialis* adults newly emerged from a nest.



Figure 6. Nest-parasitic moths from the nests of the invasive alien hornet, *V. velutina nigrithorax*. (**A**) The primary nest of *V. velutina nigrithorax* infected by *P. regalis* (Andong, Nest 11), with wasp workers remaining until early August; (**B**) adult *P. regalis* from Nest 11; (**C**) Nest 11, where most of the comb was parasitized by *P. regalis*; (**D**) *P. regalis* larvae occurred from Nest 10, of which most of the cells were covered by a silk web of the larvae; (**E**) the primary nest parasitized by *H. mauritialis* (Jinju, Nest 38), there were no workers in the nest in early August; (**F**,**G**) *H. mauritialis* larvae and adults found in Nest 37 (found dead in nests kept indoors). See Table 1 for the nest numbers.

3.4. Parasitic Moths from Invasive Social Wasp Nests

P. regalis and *H. mauritialis* occurred from the nests of the invasive alien hornet, *V. velutina nigrithorax*. The larvae of *P. regalis* were discovered in six mature nests after November. These nests were kept indoors during winter, and the adults emerged in February–March, after overwintering. However, in the Noha-dong and Andong nests, seven adult moths (Figure 6B) were collected from both the inside and outside of the nest on August 3rd, and 36 larvae (Figure 6D) were also found. A high percentage (91.6%) of the cells (2 combs, total cells 797, infected cells 730) were heavily covered with a silk web spun by the moth larvae (Figure 6C), while only 13 wasp workers still remained on the nests (Figure 6A). *H. mauritialis* was found in two nests (Figure 6E). In the first nest, 11 adults (Figure 6G) and four larvae (Figure 6F) were collected from the discarded nests between January and March, and in the second nest, six adults and 8 larvae were collected in August. At this time, both nests had three combs, with most of the first two combs being infected, and the third comb was not infected at all. Unfortunately, the total number of cells could not be measured because of the damage on the nests.

4. Discussion

4.1. Occurrence of Moths in Social Wasp Nests

P. regalis appeared to be the most widespread moth species in Korean social wasp nests, parasitizing the nests of 11 different host species within three genera, namely *Vespa*, *Dolichovepula*, and *Polistes*. With the exception of *V. binghami* (du Buysson, 1905), *P. regalis*

was found in almost all *Vespa* species (eight in total, excluding two subspecies) found in the Republic of Korea [17]. The nest of *V. binghami*, being a rare nocturnal wasp, has never been observed in the Republic of Korea, and the parasitism status of the moth on this particular wasp is still unknown. The subspecies *V. simillima xanthoptera* (Cameron, 1903) is restricted to Jeju Island and has not been adequately studied. Although *P. regalis* reportedly infests *V. simillima* [42], it is highly likely that this moth also infests *V. simillima xanthoptera* nests. Thus, *P. regalis* is capable of parasitizing the nests of most *Vespa* species. Moreover, the moth occurs in the *Polistes* species as well, as recorded in *P. yokahamae*, *P. nipponensis*, and *P. rothneyi koreanus* [23]. Notably, the nest parasitization of *P. regalis* has been observed for the first time in the genus *Dolichovespula*, namely *D. kuami*, a species endemic to the Republic of Korea in the present study. However, *P. regalis* has never been found in the nests of any *Vespula*. While moths have been found in the nests like *Vespula*, at present, it is unclear why the moth does not occur in the nests of the *Vespula* species.

A. japonica occurred in *P. rothneyi koreanus* nests in the Republic of Korea [23] and *P. chinensis antennalis* (Perez, 1905) nests in Japan [8]. In our study, *A. japonica* was found to infest the nest of *V. crabro flavofasciata* for the first time; therefore, this moth can parasitize *Vespa*, as well as *Polistes*, much like other moth species. However, ecological and biological information on these species is still lacking, and further sample and host investigations are required.

Two species in *Hypsopygia*, namely *H. mauritialis* and *H. postflava* (Hampson, 1893), were previously recorded, occurring in the nests of social wasps in Japan, and their identification is challenging due to their similar appearance [16]. The *Hypsopygia* species are mostly known to parasitize the nests of Polistinae wasps [5,6,43], with an exception of *H. mauritialis*, which has also been found in the nest of *V. affinis* (Linnaeus, 1764) in Japan [13]. Although these two *Hypsopygia* species were not previously reported from the Republic of Korea, and their morphology closely resembles *H. regina* (Butler, 1879) [24,42], we confirmed their identity as *H. mauritialis* based on their external morphology, genitalia structure, and DNA barcoding. In the Republic of Korea, *H. mauritialis* was newly discovered in Jinju in 2021 and subsequently found in Jeonju, Gurye, and Seongju in the southern region of the country, suggesting its wide distribution in the region. Given its occurrence in *Vespa* and *Polistes*, it appears to have a similar host preference to *P. regalis*.

4.2. First Occurrence in Invasive Alien Social Wasp Nests

The invasive alien hornet, *V. velutina nigrithorax*, which was introduced to the Republic of Korea from China in 2003, has spread throughout the Republic of Korea [18,44] and Europe, causing negative impacts [45]. Only few natural enemies of this hornet were ever documented in Europe and the Republic of Korea, where the conopid fly [46], nematode [47], and marten [48] have been studied as predators. Therefore, the occurrence of *P. regalis* and *H. mauritialis* is the very first record of nest-parasitic moths of *V. velutina nigrithorax* in an invaded country, the Republic of Korea.

When bees and ants (other social insects) are infected by parasites such as viruses, mites, and fungi, their colonies often collapse [49–52]. However, colony collapse due to parasitism is rare in social wasps, indicating that their ability to control such parasites is significant [46,47,53]. Compared with other parasites, these parasitic moths do not affect the brood of wasp hosts directly, not as an obligatory parasite, but rather disrupt the development of nests in feeding, webbing, and occasional predation on larvae or pupae in social wasp nests [5,6,8,13,16] (see also [1]).

In general, for *Polistes* nests with small colonies, if the moth infection rate is high, colonies often collapse (Figure 4C,E) due to the feeding activity of the moth larvae (Figure 4F) [11,54,55]. However, large colonies such as the *Vespa* species are known to have little impact [13].

For *P. regalis* development within *V. velutina nigrithorax* nests between November and December, some larvae were found in the uppermost combs of the discarded mature nests,

which appeared to give little negative impact on the colonies. However, when the nests were discovered in August, during periods of rapid expansion, such as Nests 11 and 38 (Table 1), few combs were almost entirely infested (Figure 6C), and there were limited numbers of hornet larvae, pupae, and adults remaining (Figure 6A). As this is the time when *V. velutina nigrithorax* relocates from the primary to the secondary nest [56], it seems that the nest gradually emptied due to the movement of *V. velutina nigrithorax*, rather than the colony collapsing, allowing the moths to occupy the entire nest. Therefore, these nest-feeding moths do not appear to significantly affect the maintenance of *V. velutina nigrithorax* colonies.

5. Conclusions

This study identified three nest-parasitic moths from social wasp nests in the Republic of Korea, including the newly recognized *H. mauritialis*, along with *P. regalis* and *A. japonica* that were previously recorded. Additionally, over the course of a decade-long search, a total of 11 species within three genera of hosts were newly recorded. Notably, this study identified, for the first time, *P. regalis* and *H. mauritialis* extensively feeding in the nests of *V. velutina nigrithorax*, the invasive alien hornet in the Republic of Korea. While these parasitic moths may have potential as natural enemies of social wasps, they do not appear to have a significant controlling effect when a rapid response is required, such as in situations where social wasps are increasing in urban areas or when invasive social wasps are rapidly spreading.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d15060789/s1, Table S1: Collected location of social wasp nests.

Author Contributions: Conceptualization, M.B.C. and C.-J.K.; methodology, Y.-M.S., I.-K.K. and M.B.C.; formal analysis, Y.-M.S. and M.B.C.; investigation, H.S.L. and M.B.C.; resources, M.B.C. and H.S.L.; supervision M.B.C. and C.-J.K.; visualization, Y.-M.S. and M.B.C.; data curation, M.B.C. and Y.-M.S.; writing—original draft preparation, M.B.C., Y.-M.S. and C.-J.K.; writing—review and editing, M.B.C. and I.-K.K.; project administration, M.B.C., I.-K.K. and C.-J.K.; funding acquisition, C.-J.K. and I.-K.K. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by grants from the Scientific Research [KNA1-1-25, 19-1] of the Korea National Arboretum.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: All data can be found within the manuscript.

Acknowledgments: We thank C. H. Ma for providing the host hornet nests. We also thank J. H. Kim for collecting *H. mauritialis* individuals from invasive hornet nests.

Conflicts of Interest: The authors declare no conflict of interest.

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