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Articles

Ongoing invasion and first parasitoid record of the North American leaf-mining moth Chysaster ostensackenella (Lepidoptera: Gracillariidae) in Primorsky Territory (Russia)

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The North American leaf-mining moth *Chrysaster ostensackenella* (Fitch, 1859) (Lepidoptera: Gracillariidae) is an invasive species newly documented in Russia in 2022 based on our findings in Primorsky Territory. The article provides data on its biology and distribution in the southern part of the region in 2023. A survey of *Robinia pseudoacacia* (a host plant) carried out in 12 distant settlements revealed widespread spread of *Ch. ostensackenella*: from the town of Spassk-Dalniy (44°36′N, 132°49′E) on the north to the village of Khasan (42°25′N, 130°38′E) on the south. Significant plant damage (>50% of leaves with the mines) was documented in the city of Artem and the village of Sinyi Gai, moderate (>25%) in Khasan, Bolshoi Kamen and Ussuriysk, and low damage (<10%) in other six settlements. Parasitism was recorded in two localities (Khasan and Slavyanka), reaching 22%. Altogether, six parasitoid adults (five females and one male) of *Achrysocharoides chrysasteris* Kamijo, 1990 (Hymenoptera: Eulophidae) were reared from the moth pupae. This East Asian parasitoid is a novel record for Russia, and its trophic association with the North American moth is a new to science. Diagnoses of the parasitoid genus and species are given, and the species male is newly described. Additionally, the illustrations of male and female of *A. chrysasteris* are provided.

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Keywords

Gracillariid, invasive alien species, *Robinia pseudoacacia*, the Russian Far East, distribution, parasitism, *Achrysocharoides chrysasteris*

Introduction

Introduction of woody plants largely promotes distribution of alien phytophagous insects (Bonnamour et al. 2023). One of such plants is the black locust, *Robinia pseudoacacia* L. (Fabaceae), which originates from the eastern United States (Huntley 2023). Bearing in mind its qualities for landscaping, this North American species has been used by humans for few centuries and, as a result, nowadays, it is widely distributed across Eurasia, South America, Australia, and the southern regions of Africa (Vítková et al. 2020). In some countries, including Russia, this North American plant got naturalized (Kleinbauer et al. 2010; Richardson and Rejmánek 2011; Uzelac et al. 2023) exhibiting a propensity for autonomous colonization, penetrating forests and competing with local plant species (Vinogradova et al. 2014, 2020; Kozhevnikov et al. 2019).

In Eurasia, the North American insect species which are associated with the black locust in its native range got widely distributed (Mally et al. 2021; Medzihorský et al. 2024). Among them, for instance, there are the sawfly *Nematus tibialis* Newman, 1837 (Hymenoptera: Tenthredinidae), the black locust gall midge *Obolodiplosis robiniae* (Haldeman, 1847) (Diptera: Cecidomyiidae), the leaf-mining moths *Parectopa robiniella* (Clemens, 1863), and *Macrosaccus robiniella* (Clemens, 1859) (both from Lepidoptera: Gracillariidae) (Gninenko 2007; Gninenko and Yurchenko 2009; Martynov et al. 2018, 2020; Kolyada et al. 2022). Notably, the leaf-mining moths (Lepidoptera: Gracillariidae) are among the most successful invaders enabling to outbreak in new regions and continue spreading (Kirichenko et al. 2019; Belitskaya et al. 2020).

In the Far East, *R. pseudoacacia* has been cultivated since early 20th century and is currently distributed in the Primorsky Territory up to the border with Khabarovsk Territory (Kolyada 2021). Between 2019 and 2023, at the Mountain Taiga Station (the branch of the Federal Scientific Center for Biodiversity, village of Gornotaezhnoe), the specialized pests of *R. pseudoacacia*, such as *Nematus tibialis*, *Obolodiplosis robiniae*, and *Platygaster robiniae* Buhl & Duso, 2007 (Hymenoptera: Platygastridae), the egg-larval endoparasitoid of *O. robiniae* were recorded (Kolyada et al. 2022, 2023). In 2022, the North American leafminer *Chrysaster ostensackenella* (Fitch, 1859) (Lepidoptera: Gracillariidae) was also detected in the region representing the first record for Russia (Kirichenko et al. 2023).

Chrysaster ostensackenella is a North American species which larvae feed and live in upper-side blotch mines on the leaves of *Robinia pseudoacacia* (Braun 1908). Outside of its native range, the moth was discovered in China in 2015 (Bai et al. 2015; Liu et al. 2015), following by the records in the Republic of Korea in 2017 (Koo et al. 2019), Japan in 2020 (Sawada and Sakurai 2022), Europe (Italy) in 2022 (Huemer, Mayr 2022), and Russia in 2022 (Kirichenko et al. 2023).

Here we studied the pest bionomics and explored its distribution in Primorsky Territory in 2023, as well as detected a native parasitoid species which switched to a new invader.

Materials and methods

The study was carried out in June–September 2023 in *R. pseudoacacia* plantings in 12 settlements of Primorsky Territory: the cities of Artem, Arsenyev, Bolshoi Kamen, Partizansk, Spassk-Dalniy, Ussuriysk, the villages of Sibirtsevo, Slavyanka, Khasan, and the villages of Gornotaezhnoe, Khorol, Siny Gai (Fig. 1).

In each locality, from 10 to 20 trees were examined. The leaves were checked on ten low branches around tree crown for the presence of blotch leaf mines following earlier techniques (Kirichenko 2014; Lopez-Vaamonde et al. 2021). The following parameters were recorded: the number of leaves with the mines per branch, the number of leaflets with mines per leaf, the number of mines per leaflet. The average values of these parameters were calculated for each of the 12 studied localities. The plant damage was estimated as a ratio of leaves with the mines to the total number of leaves on examined branches and expressed as %. The nonparametric Mann-Whitney U-test was used to compare the parameters between studied localities (Mann and Whitney 1947).

From 5 to 20 leaflets with the mines were randomly collected from trees in each locality. They were packed in ziplock bags with label and transported to the laboratory of the Mountain Taiga Station (Gornotaezhnoe) for rearing larvae and pupae to adult moths. The leaflets with the mines were kept in the shade under constant conditions (temperature +25℃, humidity 60%).

In the first half of October 2023, 12 ziplock bags containing a total of 168 leaflets with the mines (already dried by that time) were transported to the Department of Forest Zoology at the Institute of Forestry SB RAS (Krasnoyarsk) for moth identification and further study. The bags were examined to collect emerged moth adults, and the mines on leaves were dissected to examine the moth larvae and estimate parasitism. Before dissecting the leaf mines, the leaflets were moistened by placing them in Petri dishes on moderately wet filter paper disks for 4–6 hours. This was done to facilitate the dissection of mines with minimal damage to the leaves, enabling the herbarization of the studied material after the manipulations. The leaf mines were inspected at 5–32× magnification under a Zeiss Stemi DV4 stereomicroscope (Germany) using both reflected and transmitted light. The larvae found within the mines and pupae dissected from the cocoons on the leaflets were examined for the presence of parasitoids.

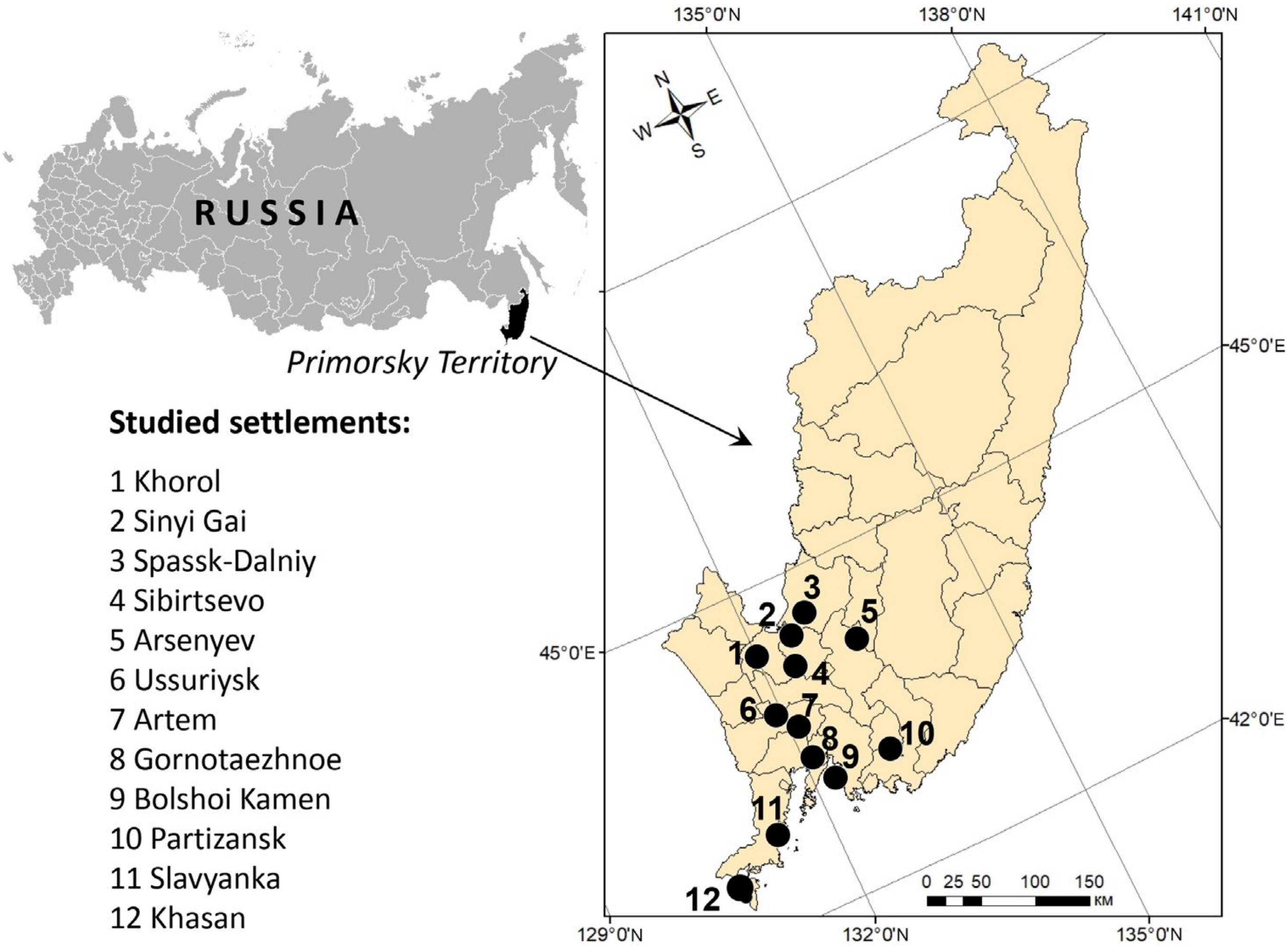

Figure 1. *Studied settlements in Primorsky Territory in 2023.*

During the examination of herbarized specimens, following data were documented: (1) the number of emerged moth adults, (2) the number of moth larvae, (3) the number of moth pupae, and (4) the number of emerged parasitoids. For parameters 2 and 3, the larvae and pupae (were all dead and had no signs of parasitism) were considered as those that did not complete development due to premature drying of leaflets. The ratio of parameters 1–3 to the number of examined mines was estimated, considering that one moth larva developed in one mine, and one moth pupa was present in one cocoon, and expressed as %.

To estimate parasitism, the data on parasitoids were divided to two, considering that typically two parasitoids emerged from a single moth pupa in two cases. This was confirmed by finding two pupal exuviae of parasitoids next to one pupal exuvium of the moth in a cocoon. The adults of parasitoids were identified based on morphological characteristics using following publications: Askew and Ruse (1974), Bouček (1988), Bryan (1980), Hansson (1983), Yoshimoto (1977), and Kamijo (1990a, 1990b, 1991).

Morphological terminology follows Gibson (1997) and Kamijo (1990a), morphological abbreviations follow Hansson and Shevtsova (2010). Following abbreviations are used in the text: HE – height of eye; HW – height of forewing; LG – length of gaster; LM – length of marginal vein; LW – length of forewing, measured from base of marginal vein to apex of wing; MM – length of mesosoma; MS – malar space; OOL – distance between one posterior ocellus and eye; PM – length of postmarginal vein; POL – distance between posterior ocelli; POO – distance between posterior ocelli and occipital margin; ST – length of stigmal vein; WH – width of head; WM – width of mouth; WT – width of thorax.

Photographs of leaves with the mines were taken using a Sony Alpha 5 digital camera (Sony Corporation, Tokyo, Japan). In the laboratory, the mines, larvae, pupae, and adult moths were photographed using the digital camera of a Xiaomi 11 Lite smartphone (Beijing, China, Xiaomi Corporation) through the Zeiss Stemi DV4 stereomicroscope. Photographs of adult parasitoids were captured with a Canon EOS 70D digital camera mounted on an Olympus SZX10 microscope (Zoological Institute RAS, St. Petersburg). The images were adjusted using Adobe Photoshop 23.5.0.

Result

I. **Biology of *Chrysaster ostensackenella***

In Primorsky Territory, *Ch. ostensackenella* mines were found exclusively on the North American tree, *Robinia pseudoacacia*. According to our observations, the moth undergoes at least two generations in this region: the first from mid-May to mid-July, and the second from late July to early September; the presence of the third generation is uncertain.

Moths lay eggs on the upper side of leaflets, so that the mines are also located on the same side (Fig. 2A, B). In one out of 142 cases (0.7%), young mine was documented on the lower side of the leaflet.

After hatching from eggs, the larvae penetrate the epidermis and feed on the palisade parenchyma, gradually expanding and deepening the mine (Fig. 2C, D). The mines are typically rounded or elongated flat blotches, positioned on one side of the leaflet (Fig. 2A, E). They can extend over the central vein but only in the apical part of the leaflet (where central vein is thin and easy to cross). Fresh mines are gray; upon herbarization, they become light gray or greenish-yellowish (Fig. 1A, B, E). Frass grains are visible only under transmitted light (Fig. 2A–D). The blotch mine may be preceded by a short epidermal tunnel, where frass is compactly located in the form of a central, relatively wide line. Within the blotch mine, frass grains are dispersed on the bottom, mostly concentrated in its central part, while the mine edge remain free from frass (Fig. 2A, B). The frass grains are attached to the bottom of the mine, and when dissected (i.e., when the upper epidermis is removed), they do not spill out.

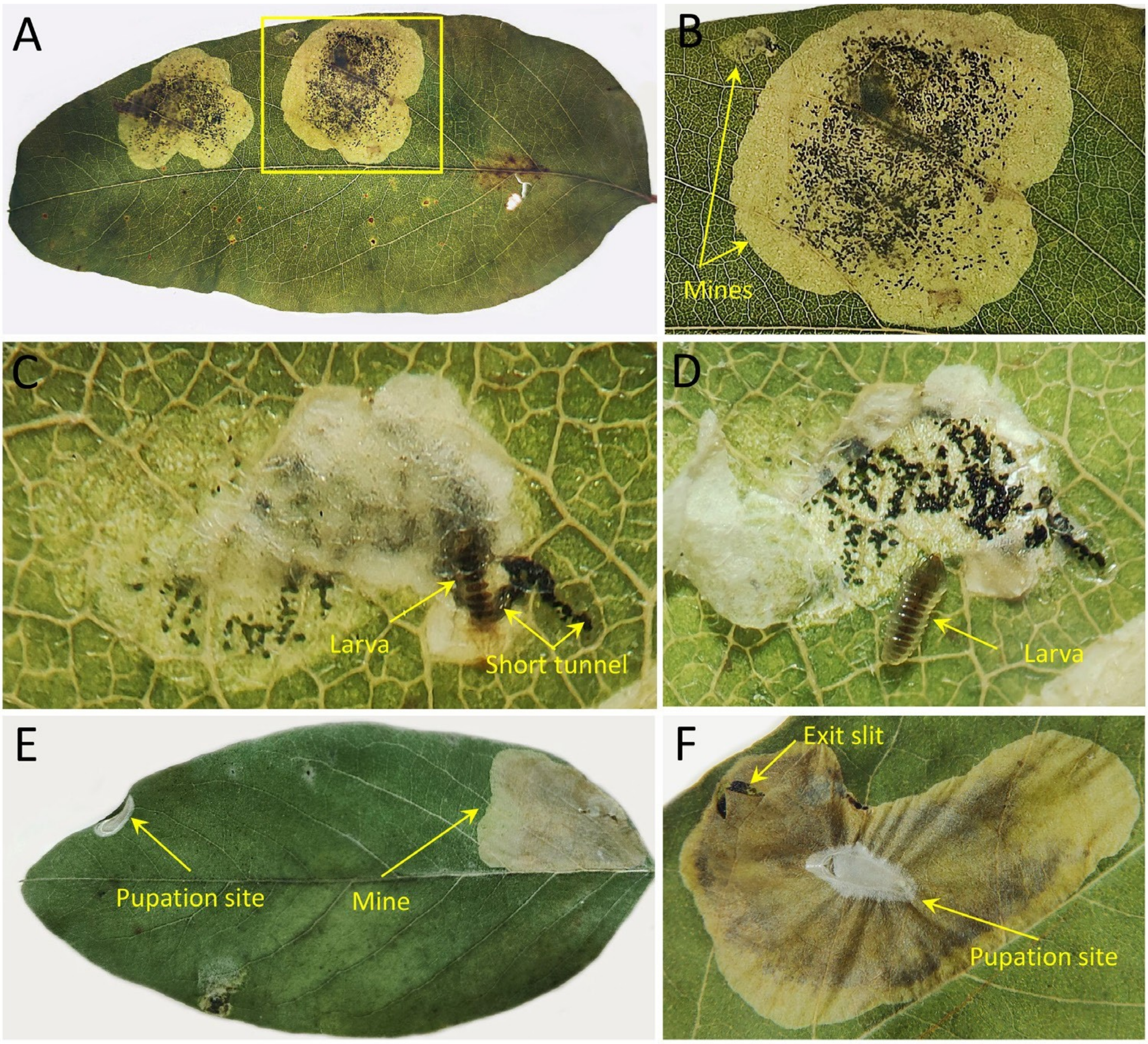

Figure 2. *Upper side blotch mine of Chrysaster ostensackenella on leaflets of Robinia pseudoacacia in Primorsky Territory, July–September 2023 (herbarized material). (**A**) three mines on the upper side of the leaflet (the details of the two mines are shown in **B–D**); (**B**) young and old mines with frass granules; (**C**) young mine with a preceding short epidermal tunnel densely filled with frass; (**D**) opened mine; (**E**) the leaflet with an old mine at the base and the pupation site at the edge in the apical part; (**F**) an old mine with larval exit slit and the pupation site. Photos: N.I. Kirichenko.*

The young larva has flat body with dark plates located on the body segments dorsally (Fig. 2D). Prior to pupation, larvae exit the mines through roundish cut in the upper epidermis. Pupation takes place within a dense white silk cocoon, typically situated on the upper side of the leaflet (most often at the leaflet edge, but also can be on the upper epidermis covering the mine), occasionally on the lower side of the leaflet. Silk threads, by which the cocoon is being attached to the leaflet, soon contract and cause slight deformation of the leaflet, somewhat bending the leaflet edge upwards or proving waviness on the epidermis covering the mine (Fig. 2E, F). When the leaf mines were stored in plastic ziplock bags, larvae leaving the mines often pupated on the walls of the bag.

The cocoon is white; in transmitted light, the pupa is visible in the cocoon (Fig. 3A). The young pupa is dark green, later gets brown (Fig. 3B). After moth emergence, the pupal exuvium protrudes halfway from the cocoon (Fig. 3C, D). The moth is relatively small, with a wingspan of up to 4.2 mm. The forewings are with a characteristic pattern, featuring a rufous base color with dark and silver streaks (Fig. 3E). Detailed diagnostic features of the moth are provided in earlier studies (Koo et al. 2019; Sawada, Sakurai 2022). Illustrations of the male genital apparatus can be found in Huemer, Mayr (2022) and Kirichenko et al. (2023).

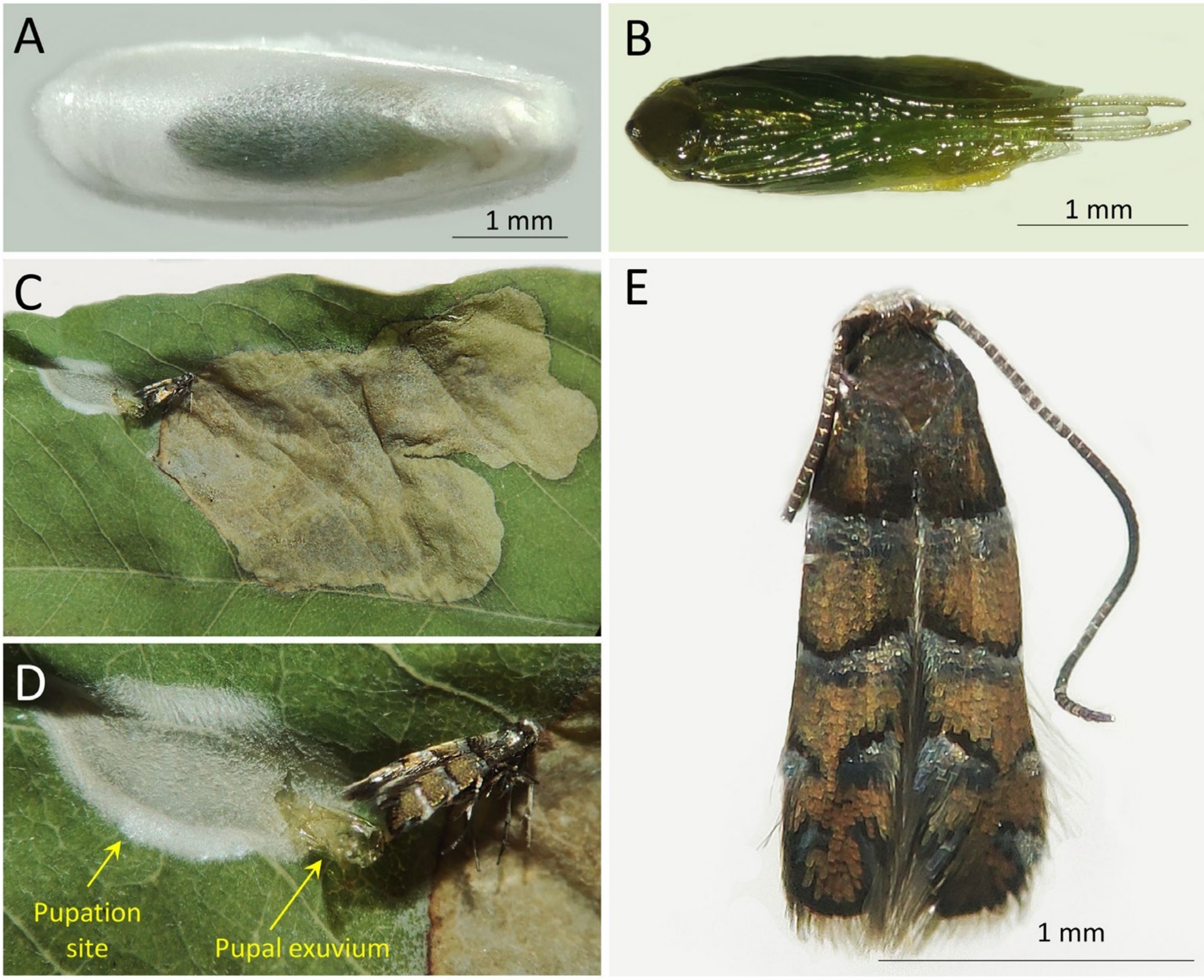

Figure 3. *The pupa and the moth of Chrysaster ostensackenella, Primorsky Territory, July– September 2023 (herbarized material). (**A**) silk cocoon with pupa; (**B**) pupa, ventral view; blotch mine and pupation site; (**D**) emerged adult and pupal exuvium protruding from the cocoon; (**E**) moth, dorsal view. Photos: N.I. Kirichenko.*

II. Damage caused to *Robinia pseudoacacia*

In the studied localities, the level of damage caused by *Ch. ostensackenella* to its host varied (Fig. 4, Table 1). *Robinia pseudoacacia* suffered significant damage in Artem (Artemovsky district), where the proportion of damaged leaves (i.e. those with the mines) on examined trees reached 83% (Fig. 4). Up to 4 mines per leaflet were documented (Fig. 5). In this locality, *R. pseudoacacia* is extensively used in landscaping and propagates extensively through vegetative reproduction (Kolyada: personal observation in 2023).

Similar damage (72%) was documented in Sinyi Gai (Chernigovsky district) (Fig. 4, Table 1). On the outskirts of the village, two stands of *R. pseudoacacia* were present on both sides of the road covering an area of about two hectares, and the leaf mines of *Ch. ostensackenella* were abundant in both stands.

In three localities, Khasan, Bolshoi Kamen and Ussuriysk, moderate damage (slightly over 25%) was noted (Fig. 4, Table 1). In some cases, two mines were present on the leaves (Table 1). In the remaining seven settlement localities, the damage was low, with the proportion of leaves with mines on studied plants not exceeding 10% (Fig. 4, Table 1).

According to our observations in 2023, the town of Spassk-Dalniy (44°36′N, 132°49′E) represented the northernmost point of *Ch. ostensackenella* distribution in Primorsky Territory, while the village of Khasan represented the southernmost record (42°25′N, 130°38′E).

Settlement	Number of examined trees; [branches]		Mean number of		Damage level (% of leaves with the mines)
		leaves with the mines on branches; (min-max)	leaflets with the mines within leaves; (min-max)	mines on leaflets; (min-max)	
Artem	20 [10]	15±8 a	7.5±2.3 a	2±1.2 a	83 a
		(7–23)	(1–14)	(0–4)	
Sinyi Gai	20 [10]	13±6 a	7.5±2.1 a	1.5± 0.6 ab	72 a
		(9–17)	(1–14)	(0–3)	
Khasan	20 [10]	5±1.2 b	3.5±1.1 b	1±0.5 ab	27 b
		(0–10)	(0–7)	(0–2)	
Bolshoi Kamen	20 [10]	4.9±1.1 b	2.9±1.0 b	1±0.5 ab	27 b
		(0–9)	(0–5)	(0–2)	
Ussuriysk	10 [10]	4.7±1.0 b	2.7±0.9 b	1±0.4 ab	26 b
		(0–9)	(0–5)	(0–2)	
Khorol	20 [10]	1.5±1.1 c	1±0.4 c	0.5±0.4 b	8 c
		(0–3)	(0–2)	(0–1)	
Slavyanka	20 [10]	1±0.5 c	1±0.5 c	0.5±0.4 b	6 c
		(0–2)	(0–2)	(0–1)	
Arsenyev	20 [10]	1±0.7 c	1±0.4 c	0.5±0.3 b	6 c
		(0–2)	(0–2)	(0–1)	
Sibirtsevo	20 [10]	1±0.6 c	1±0.3 c	0.5±0.5 b	6 c
		(0–2)	(0–2)	(0–1)	
Partizansk	10 [10]	1±0.6 c	1±0.4 c	0.5±0.5 b	6 c
		(0–2)	(0–2)	(0–1)	
Spassk-Dalniy	10 [10]	1±0.7 c	1±0.5 c	0.5±0.2 b	6 c
		(0–2)	(0–2)	(0–1)	
Gornotaezhnoe	20 [10]	1±0.9 c	1±0.4 c	0.5±0.3 b	6 c
		(0–2)	(0–2)	(0–1)	
Khorol	10 [10]	1±0.8 c	1±0.3 c	0.5±0.2 b	6 c
		(0–2)	(0–2)	(0–1)	

Table 1. *The infestation of Robinia pseudoacacia trees by Chrysaster ostensackenella in 12 settlements of Primorsky Territory in 2023*

Note: within columns, the values indicated by different letters are significantly different at $p < 0.05$ (the Mann-Whitney U-test).

III. Development success and parasitism rate

Under laboratory conditions, the proportion of moth larvae and pupae which successfully completed development (i.e., grew to adults) varied in the studied regions from 42% (Sinyi Gai) to 100% (Slavyanka) (Fig. 6). The lower percentage of emerged moths in some localities, such as Sinyi Gai, Khasan, Partizansk, etc. (Fig. 6), was attributed to the failure of larvae from two overlapping generations to complete their development in laboratory conditions due to premature leaflet drying. Thus, the percentage of emerged adults could be significantly higher in natural conditions than recorded indoor.

In two of 12 studied localities, namely Slavyanka and Khasan, a total of six parasitoid adults emerged from pupae of *Ch. ostensackenella*, i.e., five females (Slavyanka) and one male (Khasan). In Slavyanka, four out of five parasitoid individuals occurred from two moth pupae, indicating that two parasitoid individuals developed within each pupa of the moth. The parasitism rate in moth populations was approximately 22% in Slavyanka and 10% in Khasan (Fig. 6). Remarkably, in these two localities, *R. pseudoacacia* was damaged at low level in Slavyanka and at moderate level in Khasan. Conversely, in localities where the trees were significantly damaged by the moth, and, thus, the mines were easy detectable, not a single parasitoid was recorded.

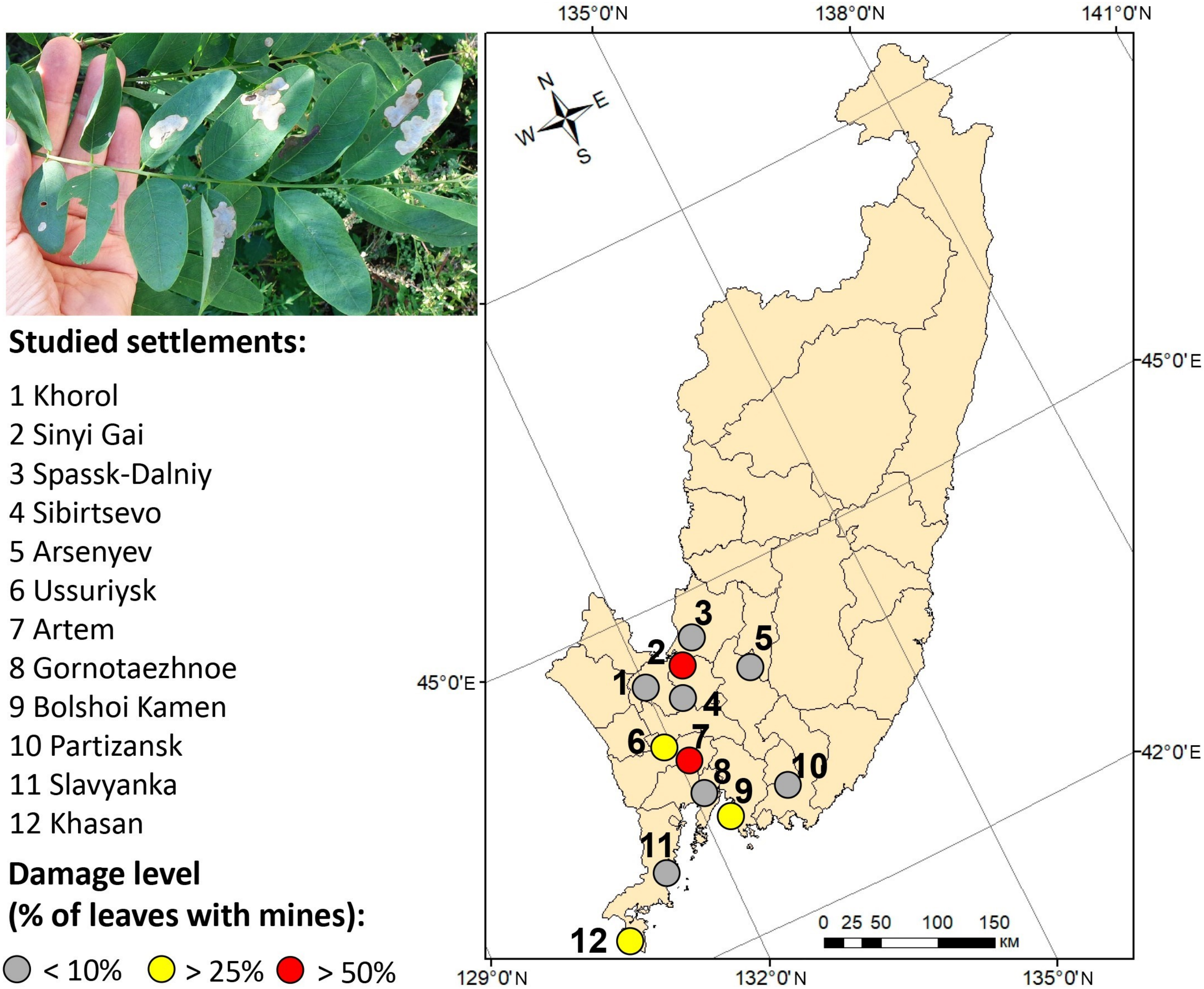

Figure 4. *Robinia pseudoacacia damage levels in 12 studied localities in Primorsky Territory in 2023.*

Another interesting observation is that Khasan and Slavyanka, both belonging to Khasansky district, represent the southern points, where the moth pupae were parasitized (Fig. 6). The southernmost settlement (Khasan) is located just 9 km from the border with China.

IV. First record of the parasitoid *Achrysocharoides chrysasteris*

The parasitoid individuals grown from the moth pupae at two localities (Slavyanka and Khasan) were identified by the adult morphology as *Achrysocharoides chrysasteris* Kamijo, 1990. Below, the genus and species diagnoses are given, as well as the male is described (prior to our studies, the male of this species was not known). Additionally, the original photographs of female and male adults are provided with morphological structures indicated.

Order Hymenoptera Linnaeus, 1758

Superfamily Chalcidoidea Latreille, 1817

Family Eulophidae Westwood, 1829

Subfamily Entedoninae (Foerster, 1856)

Genus *Achrysocharoides* Girault, 1913

Type species: *Chrysocharis sarcophagus* Girault by original designation. A complete list of genera synonymized with *Achrysocharoides* is given by Hansson (2012).

Diagnosis (as per Hansson, 2012). Eyes densely pubescent; females with frontal suture as a raised carina (i.e. with frons just above frontal suture protruding), straight; males with frontal suture straight to slightly V-shaped, sometimes missing; females with antennal scrobes indistinct (i.e. not as narrow grooves) joining below frontal suture; lateral downsloping part of pronotum with a longitudinal carina; postmarginal vein short, 0.5–1.5× as long as stigmal vein.

Hosts. Species of *Achrysocharoides* develop as koinobiont endoparasitoids on larvae of leaf mining moths of the family Gracillariidae, mainly *Phyllonorycter* Hübner 1822, on trees, shrubs, and occasionally herbs (e.g. Askew, Ruse 1974; Bryan 1980, Hansson 1983). In Japan species of *Achrysocharoides* were reared also from *Liocrobyla* Meyrick, 1916, *Spulerina* Vári, 1961, *Chrysaster* Kumata, 1961, *Hyloconis* Kumata, 1963, and *Neolithocolletis* Kumata, 1963 (Kamijo 1990a).

Distribution. Presently, *Achrysocharoides* comprises a total of 70 species distributed as follows: 23 species in Europe (including European part of Russia) (Bouček, Askew 1968; Askew, Ruse 1974; Hansson 1983, 2016; Hansson, Shevtsova 2010; Navone 2006), 22 species in North America (Miller 1962; Yoshimoto 1977; Kamijo 1991; Hansson, Shevtsova 2010; Shevtsova and Hansson 2011), 10 species in Japan (Kamijo 1990a, 1990b), and 10 species in tropical America (Hansson, Cave 1993; Hansson 2012). Only three species are common to both Europe and North America: *A. robiniae* Hansson & Shevtsova, 2010, *A. splendens* (Delucchi, 1954) and *A. zwoelferi* (Delucchi, 1954). Two species are known from the Russian Far East (Kosheleva et al. 2022), and one species occurs in both Europe and Turkmenistan (Durdyev et al. 1992). Only a few species have been reported from other regions, including Australia (Girault 1913, 1915; Bouček 1988), Nepal (Hansson 1985), New Zealand (Bouček 1988), Pakistan (Hansson 1985), Papua New Guinea (Bouček 1988), and China (Shaanxi) (Yang et al. 2015).

***Achrysocharoides chrysasteris* Kamijo, 1990**

Figs 7A-G, 8 A-G

Material examined. 5 females, Primorsky Territory, Khasanskiy District, Slavyanka, reared from pupae of *Chrysaster ostensackenella* on *Robinia pseudoacacia*, VII.2023 (leaf with mines and externally situated cocoons coll.), IX.2024 (par. em.), N.A. Kolyada, N.I. Kirichenko coll., O.V. Kosheleva det.; 1 male, Primorsky Territory, Khasanskiy District, Khasan, reared from pupa of *Ch. ostensackenella* on *R. pseudoacacia*, IX.2023 (leaf with the mine and externally situated cocoon coll.), X.2023 (par. em.), N.A. Kolyada coll., O.V. Kosheleva det.

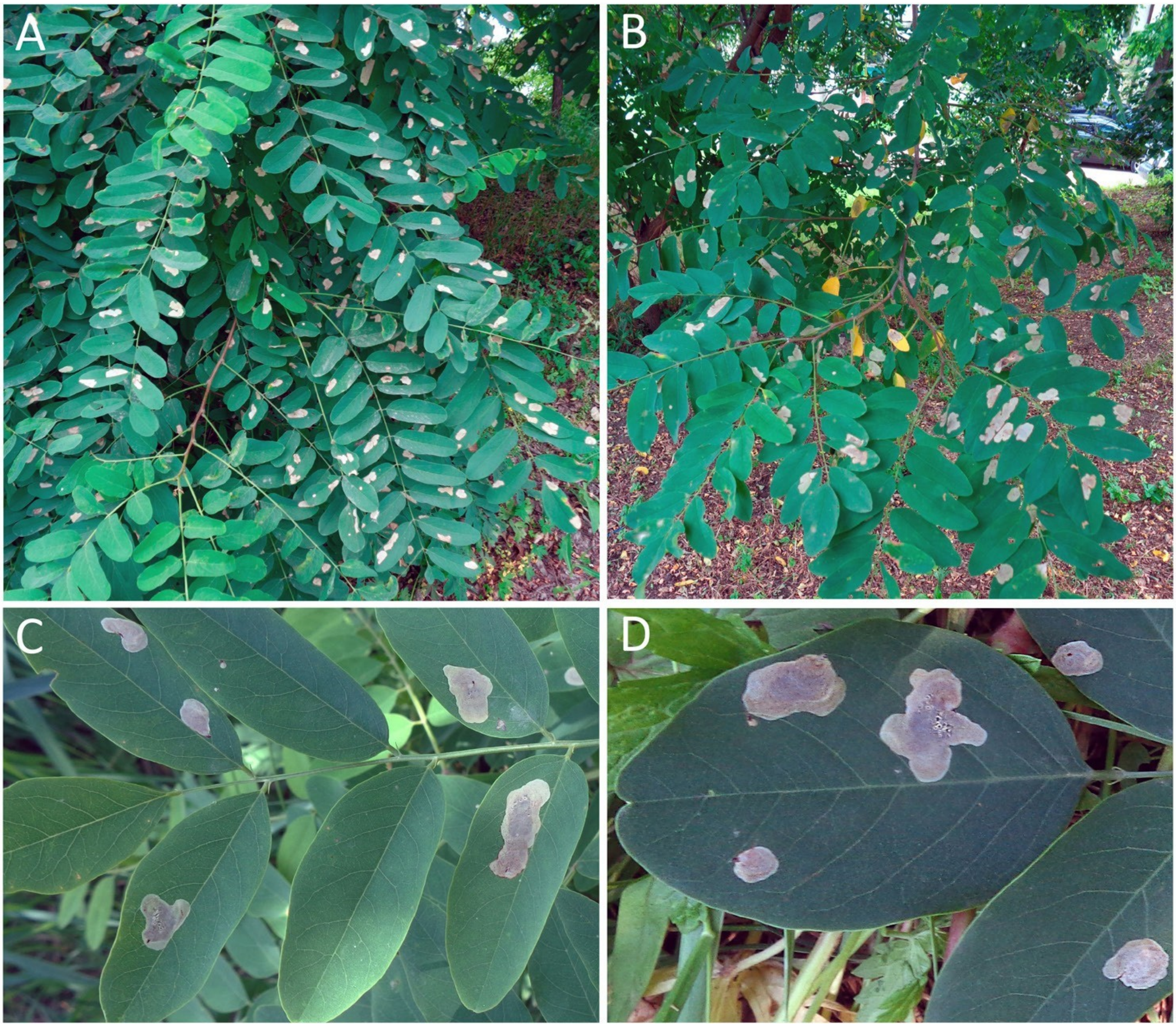

Figure 5. *Abundances of mines of Chrysaster ostensackenella on the leaves of Robinia pseudoacacia in Artem, Primorsky Territory, July 2023. (**A**, **B**) branches with mined leaves; (**C**, **D**) mines on leaflets. Photos: N.A. Kolyada.*

Diagnosis (as per Kamijo 1990a). Mid lobe of mesoscutum very strongly and coarsely reticulate, sometimes with a pair of pits; side lobes densely reticulate; transscutal suture shallow; scutellum rather flat, with reticulation much weaker and finer than on mid lobe of mesoscutum, engraved-reticulate posteriorly; a pair of pits present, each pit often longitudinally elongate and sometimes divided into two pits (Fig. 7F, G); forewing with a faint discal cloud (Fig. 7C).

Comments. The Far Eastern specimens of females are the same as in the original description by Kamijo (1990a). The following ratios is based on the Far Eastern specimens of females: HE/MS/WM = 5.0/1.0/1.9; POL/OOL/POO = 1.5/1.0/1.0; WH/WT = 1.0; LW/LM/HW = 1.7/1.0/ 1.0; PM/ST = 1.2; MM/LG = 1.0–1.1. Antenna as in Fig. 8F. The description of a previously unknown male of this species is given bellow.

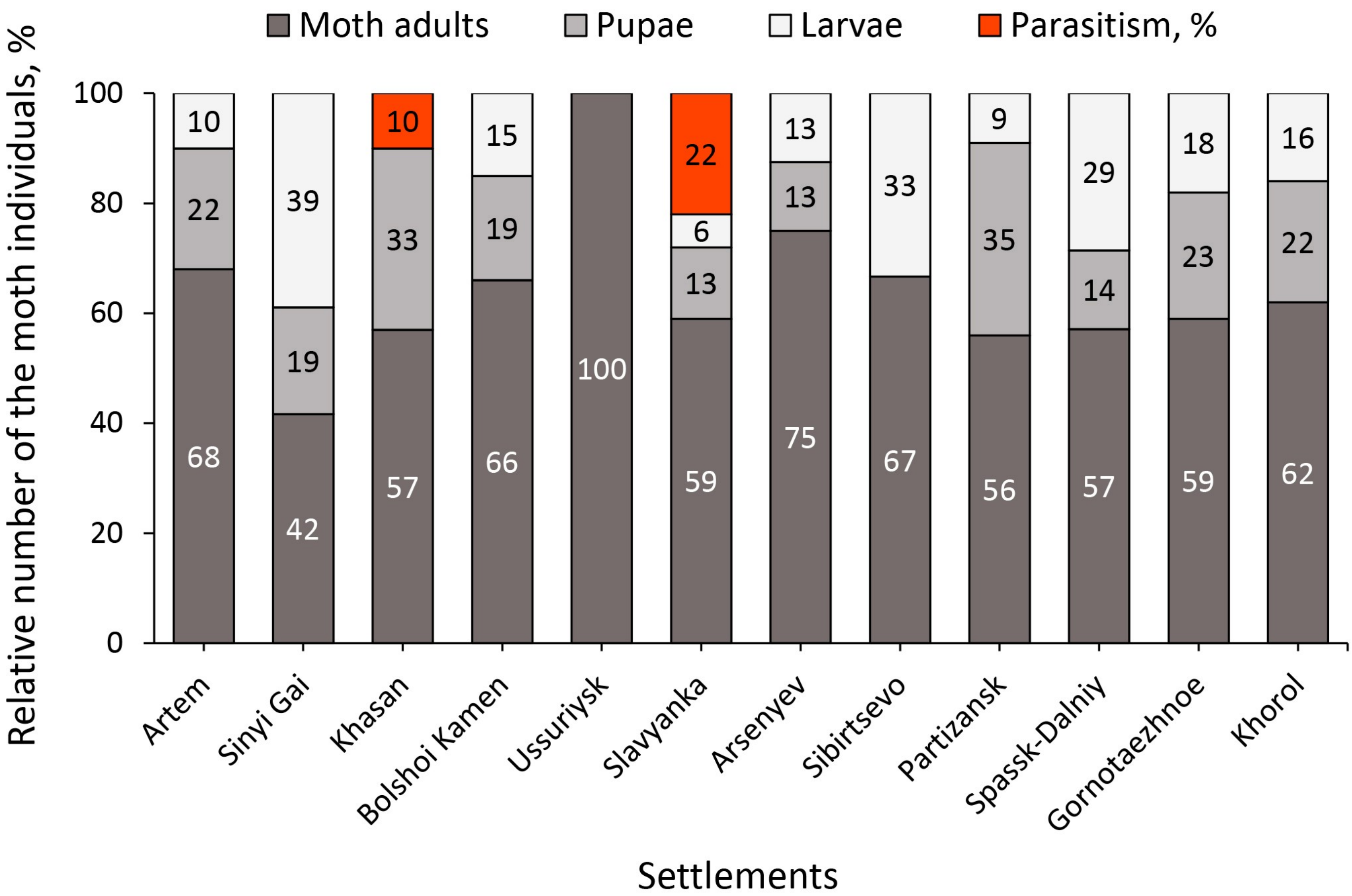

Figure 6. *The ratio of larvae, pupae and adults of Chrysaster ostensackenella emerged indoor, and the parasitism rate (%), Primorsky Territory, 2023.*

Description. Male. Body length 1.44 mm.

Scape and pedicel white; flagellum dark brown. Frons below frontal suture bright green with blue tinge, above frontal suture golden-green to golden-red. Vertex metallic golden-green, golden-reddish inside ocellar triangle. Mesoscutum, scutellum and propodeum metallic golden-green. Legs white, mid coxa with base infuscate, hind coxa with base green metallic. Fore wing with a weak median infuscate. Petiole black with metallic purple tinges. Gaster with first tergite golden-green in basal part; anteromedially with a large white spot, on dorsal and ventral sides; remaining tergites metallic dark purple with green metallic tinges (Fig. 8D).

Frons below frontal suture with transverse striae reticulation, above frontal suture medially with weak engraved reticulation and close to eyes smooth. Vertex inside ocellar triangle with engraved reticulation, outside ocellar triangle smooth. Occipital margin with a sharp edge.

Mesoscutum with midlobe with raised and strong reticulation, without pits; notaular depressions weakly reticulate to smooth. Scutellum with meshes of reticulation smaller than on midlobe, engraved-reticulate to smooth posteriorly, with pits medially on either side of imaginary median longitudinal line, each pit divided into 4 pits (Fig. 8C, see arrows). Dorsellum flat and smooth, anterolaterally with two foveae (Fig. 8C). Propodeum smooth and shiny; propodeal callus with three setae. Forewing speculum small, closed below. Petiole conical. Gaster oblong.

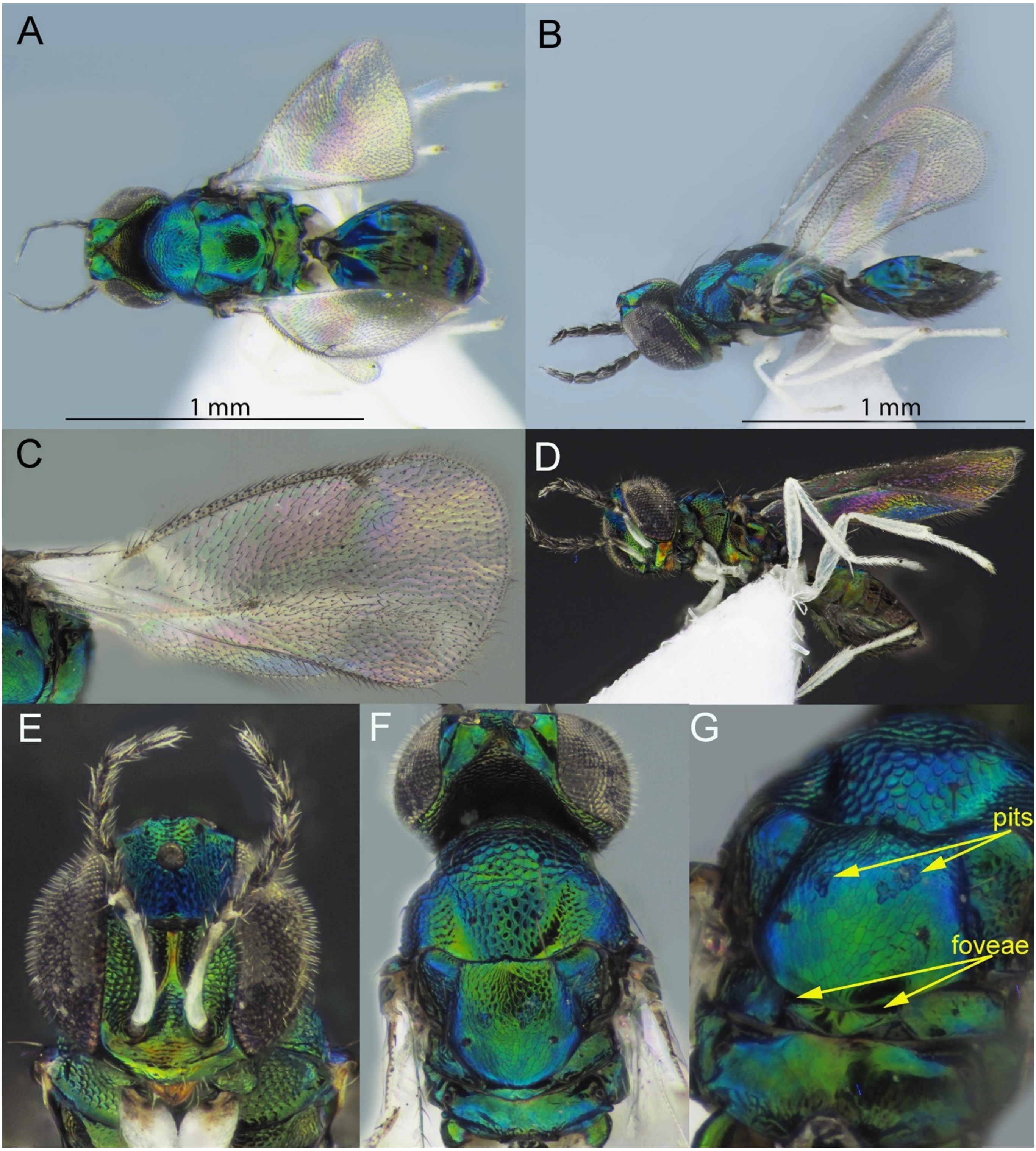

Figure 7. *A–G. Achrysocharoides chrysasteris Kamijo, female, general view and details of structure. (**A**) habitus, dorsal view; (**B**) habitus, lateral view; (**C**) forewing, part of hindwing; habitus, ventro-lateral view; (**E**) head, frontal view; (**F**) head, thoracic dorsum, dorsal view; (**G**) thoracic dorsum, posterior view. Photos: O.V. Kosheleva.*

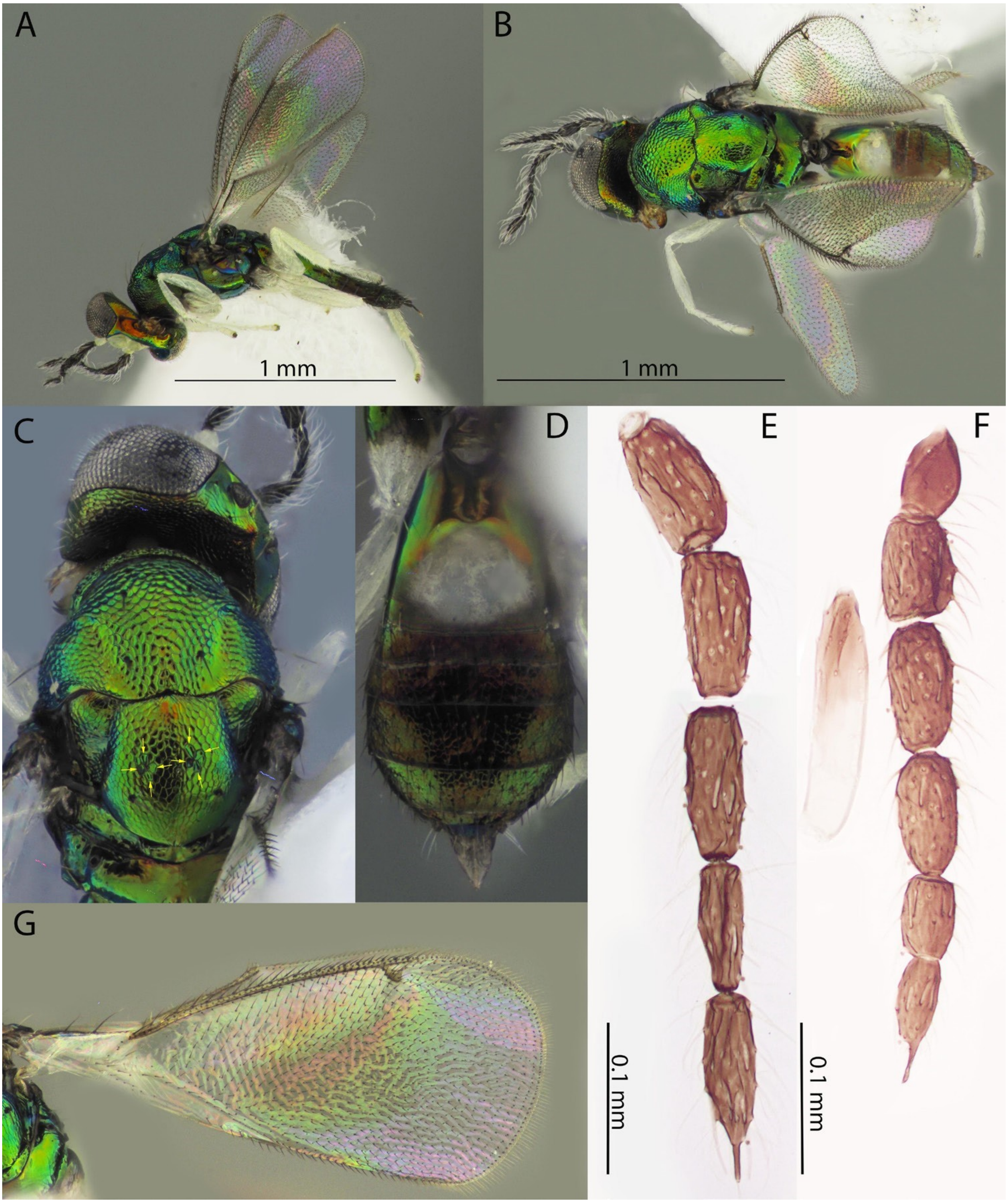

Figure 8. *Achrysocharoides chrysasteris Kamijo, male (**A–D**, **G**) and female (**F**). (**A**) habitus, lateral view; (**B**) habitus, dorsal view; (**C**) head with thoracic dorsum, dorsal view; (**D**) gaster, dorsal view; (**E**) flagellum; (**F**) scape with flagellum; (**G**) forewing. Photos: O.V. Kosheleva.*

Ratios. HE/MS/WM = 3.0/1.0/1.7; POL/OOL/POO = 2.1/1.3/1.0; WH/WT =1,1; LW/LM/HW = 1.9/1.0/ 1.1; PM/ST = 1.3; MM/LG = 1.0. Antennal flagellum as in Fig. 8E, scape 2.3 × as long as broad, pedicel 1.5 × as long as broad, 0.7 × as long as first funicle segment.

Host. Reared from *Chrysaster hagicola* Kumata, 1961 on *Lespedeza bicolor* Turcz. (Kamijo 1990a) and from *Ch. ostensackenella* (Fitch, 1859) on *R. pseudoacacia* (first record).

Distribution. Russian Far East (Primorsky Territory) (first record), Japan (Hokkaido, Honshu, Kyushu) (Kamijo 1990a).

Discussion

The opportunistic study conducted in 2023 highlights the widespread of the North American leaf-miner *Ch. ostensackenella* in the southern region of Primorsky Territory. It is worth noting that we first detected this species in the region in 2022 (Kirichenko et al. 2023). However, it would be inaccurate to assert that the species has significantly expanded throughout the southern part of Primorsky Territory within a one-year period after its initial discovery. Certainly, the moth was present in the region for some years. During seven years (2010–2017), we conducted exhaustive tree planting surveys on the territory of the Mountain Taiga Station. Despite these surveys yielded some novel records, *Ch. ostensackenella* was not observed on *R. pseudoacacia* in that period of time (Kirichenko et al. 2019).

Our findings strongly suggest that the invasion of *Ch. ostensackenella* in Primorsky Territory is recent. This assumption is further supported by the latest discovery of the species in neighboring countries (China, Korea, and Japan) between 2015 and 2020 (Bai et al. 2015; Liu et al. 2015; Koo et al. 2019; Sawada, Sakurai 2022). Previously, we hypothesized that the moth could have spread to Primorsky Territory from these countries throughout a bridgehead effect (Kirichenko et al. 2023). It is plausible that the invasion to this Russian region may have happened from Japan, especially considering that the moth individuals from Japan and Primorsky Territory shared the same haplotype (Kirichenko et al. 2023). Furthermore, it is likely that the moth invasion will continue both across the territory of Primorsky Territory and in the listed East Asian countries, where the North American black locust (the host plant of *Ch. ostensackenella*) is widely used in plantings (Li et al. 2021).

According to our observations, the North American moth has at least two generations per year in Primorsky Territory. In contrast, in China, particularly in Shandong province, it undergoes four overlapping generations annually (Liu et al. 2015). The high density of the moth populations and the presence of multiple generations per year negatively impact the host plant. In two out of 12 localities surveyed in Primorsky Territory, up to 83% of leaves on trees in the city of Artem carried the mines. Remarkably, in China, this moth damaged up to 100% of leaves on trees, resulting in wilting and premature leaf loss (Liu et al. 2015). In Primorsky Territory, *R. pseudoacacia* is predominantly found in settlements and their outskirts. The damage caused by the moth affected the ornamental appearance of trees in the city of Artem and the village of Sinyi Gai in 2023.

Notably, in 2023, we recorded a generally high survival rate of pre-imaginal stages of the moths. In laboratory conditions, more than half of larvae and pupae successfully developed to adults, in both generations. However, we suspect that adult emergence rate was underestimated. In the indoor studies, not all larvae and pupae managed to develop into adults due to premature drying of leaves in which they developed. Importantly, these larvae and pupae did not exhibit obvious symptoms of disease or parasitism. Therefore, we believe that under natural conditions the majority of them could successfully complete the development resulting in the increase of adult numbers in 2023. Thus, in the coming year (2024), the moth populations might continue growing and spreading.

The notably high survival rate of this alien pest further supports the evidence of its recent invasion into the Russian Far East. It is a common phenomenon that alien insect species, upon invading a new region, can rapidly increase density of their populations, benefiting from the absence of natural enemies (for instance, parasitoids) controlling the pest in its native habitat (Kinyanjui et al. 2021). Conversely, in the invaded region the local parasitoids and other enemies may require time to adapt to a new invasive pest before begin exerting pressure on it (Kirichenko et al. 2019). We are currently observing this invasion scenario of the North American moth in Primorsky Territory.

Interestingly, in 2023 we documented a few cases of parasitism in two out of 12 studied localities in Primorsky Territory, namely Slavyanka and Khasan. In total, six parasitoids of the eulophid species *Achrysocharoides chrysasteris* were reared from the moth pupae. This East Asian wasp species of parasitoid has been recorded in Russia for the first time. Furthermore, its trophic association with the North American moth *Ch. ostensackenella* is a new to science.

Overall, the genus *Achrysocharoides* is poorly studied in East Asia. Presently, only 13 species of this genus are known in East Asian countries. Among them, ten species are described from Japan, one species, *A. tortricidi* Yang, 2015, is known from China, and two species, *A. nagasawi* Kosheleva, 2022 and *A. carinatus* Kosheleva, 2022, were recently described from the lime leaf miner *Phyllonorycter issikii* (Kumata, 1963) (Lepidoptera: Gracillariidae) in Primorsky Territory (Kosheleva et al. 2022).

The parasitoid *A. chrysasteris* was described from Japan based on the specimens reared from a related East Asian moth species, *Chrysaster hagicola*, which develops on *Lespedeza bicolor* (Fabaceae) (Kamijo 1990a). So far, this eulophid parasitoid has not been reported outside of Japan. The Chinese authors mentioned that they obtained some parasitoids from *Ch. ostensackenella*, which, however, remained unidentified (Liu et al. 2015). Interestingly, the same study provided the first documentation of *Ch. hagicola* in China, indicating that it as a native species to the country (Liu et al. 2015). If *A. chrysasteris* was detected in China, one could suggest that *Ch. hagicola* served as a source of this parasitoid for the invasive *Ch. ostensackenella*, which recently invaded some Chinese provinces.

In Primorsky Territory, *A. chrysasteris* is likely indigenous, considering that its host, the moth *Ch. hagicola*, is a native species in the region developing on the native legume *Lespedeza bicolor* (Kirichenko et al. 2019). The cohabitation of this native plant populated by *Ch. hagicola* and the North American black locust attacked by *Ch. ostensackenella*, could facilitate the shift of the eulophid parasitoid between native and alien moth species of *Chrysaster* in the Far East.

Conclusions

Our study carried out in 2023 revealed wide distribution of the alien leaf-mining moth *Ch ostensackenella* in the south of Primorsky Territory and provided the evidences of its recent invasion into the region. This North American moth, its host plant *Robinia pseudoacacia* introduced to the Far East, and the local parasitoid species serve an excellent model system for studying invasion process among leafmining insects. Further monitoring of *R. pseudoacacia* plantations in Primorsky Territory would be needed in order to investigate response of the local parasitoid complex to this alien pest in dynamics. The knowledge gained will help to better understand the invasion success of gracillariids and the potential of the environment to absorb new alien pests.

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