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RESEARCH ARTICLE

New discoveries of Geometridae (Lepidoptera) from the extreme southwest of the Russian Far East – result of climate impact?

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Abstract

New founds of 4 species of East Asian Geometridae: *Megabiston plumosaria* (Leech, 1891), *Photoscotosia lucicolens* (Butler, 1878), *Callabraxas fabiolaria* (Oberthür, 1884), and *Dysstroma cinereata* (Moore, 1867) in the extreme southwest of the Russian Far East are presented and discussed due to the actual distribution and its current trends. From them *Ph. lucicolens* is recorded from Russia and China (Jilin) for the first time. Identity of specimens of "*Photoscotosia atrostrigata*" and "*Dysstroma cinereata*" in Barcode of Life Database is revised to *Ph. lucicolens* and *Paradysstroma corussaria* (Oberthür, 1880) respectively. These founds probably indicate northern expansion of ranges of geometrid moth in accordance with the current climatic trend of global warming. Potential harmfulness of *M. plumosaria* in RFE is assumed. The validity of *Dysstroma cinerea cesa* Koçak & Kemal, 2001, as a substitute name for *Dysstroma cinereata japonica* (Heydemann, 1929) is substantiated.

Keywords

Lepidoptera, Geometridae, distribution, ecology, new records, invasion, nomenclature, Far East, Russia, China

Introduction

The extreme southwest of the Russian Far East (hereinafter referred to as eSW RFE) borders on North Korea and Northeast China. Administratively, it is located in the Khasanskii Rayon of the Primorskii Krai. This region is one of the two southernmost territories of Russia along with southern Dagestan in the Caucasus, places between around the 42° and 43° N. Biota of the eSW RFE possesses many East Asian faunistic and floristic elements, common with Korea, Japan and China, which do not go north of this territory. In the flora, these are, for example, such prominent woody plants as *Pinus densiflora*, *Betula schmidtii* and *Rhododendron schlippenbachii*. Japanese emperor oak, *Quercus dentata*, forms its own formation in eSW RFE only. Among the geometrid moths 14 species are so far unknown to the north of this area. There are: *Alsophila vladimiri* Viidalepp, 1986, *Callabraxas fabiolaria* (Oberthür, 1884), *Dysstroma cinereata* (Moore, 1867), *Episteira nigrilinearia* (Leech, 1897), *Hemistola tenuilinea* (Alphéraky, 1897), *Heterothera postalbida* (Wileman, 1911), *Idaea trisetata* (Prout, 1922), *Idiotephria amelia* (Butler, 1878), *Luxiaria amasa* (Butler, 1878), *Maxates fuscofrons* (Inoue, 1954), *Megabiston plumosaria* (Leech, 1891), *Operophtera japonaria* (Leech, 1891), *Thinopteryx crocoptera* (Kollar, 1844), and *Xanthorhoe saturata* (Guenée, 1857 [1858]). Most of them are rare species, known from RFE for single or few specimens. In this publication, one more species is added to them, a new one for the Russia – *Photoscotosia lucicolens* (Butler, 1878); also new and unpublished finds of *C. fabiolaria*, *D. cinereata*, and *M. plumosaria* are presented. The discussion considers of these data in view of the current global warming trend. Also, nomenclatural notes on *Dysstroma cinereata japonica* (Heydemann, 1929) and *Dysstroma cinereata cesa* Koçak & Kemal, 2001, are given, with regads to correct original combination of genus and same species names of Heydemann's nominal taxa.

Materials and methods

The moths were collected on various sources of light, mainly on mercury lamps of various powers, powered by a standard electrical network or from a portable generator. The larvae were collected by hand and reared until pupation in 1987–1989 by E.A. Beljaev in Ryazanovka (Khasanskii Rayon, Primorskii Krai) on the Marin Biological Station of Far Eastern State University (now Far Eastern Federal University), Vladivostok. The materials collected by E.A. Beljaev, V.V. Dubatolov and Yu.A. Tshistjakov are kept at the Federal Scientific Center of the East Asia Terrestrial Biodiversity, those are collected by S.A. Knyazev and S.M. Saikina are kept in the private collection of S.A. Knyazev (Omsk, Russia). The order of arrangement of taxa was adopted according to Beljaev (2016) and Beljaev and Mironov (2019). In the synonymy to the species, only the original description and refers to the publications on RFE are given. Also, the data from Barcode of Life Database (BOLD, http://www.boldsystems.org) (Ratnasingham and Hebert 2007) were used and revised.

Results

Family Geometridae

Subfamily Ennominae

***Megabiston plumosaria* (Leech, 1891)**
(Fig. 1)

Biston plumosaria Leech, 1891: 43; TL: Japan: Yokohama.
Megabiston plumosaria: Viidalepp 1996: 92; Kim et al. 2001; Mironov et al. 2008: 202; Beljaev and Mironov 2019: 246; Kurina 2001.

General distribution. Russia (eSW RFE), Japan (Honshu, Izu Oshima, Shikoku, Kyushu, and Tsushima) (Nakajima and Yazaki 2011), South Korea (Kim et al. 2001; Bálint and Katona 2011; Kim et al. 2016), China (Jilin, Taiwan) (Sato and Fan 2011; Wu et al. 2020).

Distribution in RFE. Original records. Primorskii Krai, 22 km SW of Slavyanka, upper Gladkaya river, 42°47'52"N, 131°08'12"E, 10.VI.1987, E.A. Beljaev leg. – 3 larvae on *Lespedeza bicolor* (Fabaceae) and *Salix caprea* (Salicaceae), ready to pupation 27.VI.1987; ditto, 16 km WSW Slavyanka, middle Ryazanovka river, 42°50'35"N, 131°11'05"E, 12.VI.1989, E.A. Beljaev leg. – 4 larvae on *Lespedeza bicolor* (Fabaceae), *Quercus mongolica* (Fagaceae), and *Sorbaria sorbifolia* (Rosaceae), ready to pupation 22.VI.1989 and 07.VII.1989; ditto, 15 km WSW Slavyanka, middle Ryazanovka river, forestry cordon, 42°49'36"N, 131°12'22"E, at the light, 07, 08.X.1992, Yu.A.Tshistjakov leg. – 2♂♂; ditto, 36 km SSW of Slavyanka, on the eastern side of the Gamov Peninsula at the southern end of Telyakovsky Bay, 42°34' N, 131°12' E, 30.IX.-1.X.2003, at the light, E.A. Beljaev leg. – 7♂♂; ditto, 134 km SSW of Slavyanka, on the western side of the Gamov Peninsula, Vityaz, 42°35'57.63"N, 31°11'13.78"E, at the light, 25-30.IX.2020, V.V. Dubatolov leg. – 2♂♂; ditto, at the light, 9-10.X.2021, V.V. Dubatolov leg. – 12♂♂; ditto, at the light, 27-30.IX.2021, S.A. Knyazev, and S.M. Saikina leg. – 24♂♂.

Literature data. "Russian Federation, Khasanskiy rayon. 42.8 N, 131.25 E, Rjazanovka, light trap", 3, 6, 7.X.1991 – 3♂♂ (Zoological collections of Estonian Life University, Tartu) (Kurina 2001).

Notes. The localities in Russia are placed more than 600 km NE of the nearest known locality in South Korea – Gangwon-do, Hoengseong-gun, Anheung-myeon: (Ueda 2021). In North Korea and NE China, the species is still unknown. The Russian localities are about 3° north of the nethermost distribution of this species in Japan – Akita prefecture, south of Iwate prefecture (Sato, 2011); Akita, Hiraka-gun, Masudamachi, Mato (Umetsu, 2021). That distribution is unusual for species of moths with suboceanic Japanese-Korean-Eastern Chinese distribution, penetrating

to the south of RFE. In Japan, they are usually distributed farther north than in RFE, inhabiting Hokkaido, climatically characterized by a much milder winter. Apparently, the continental distribution of *M. plumosaria* is not known enough.

Larvae of *M. plumosaria* in Japan and Korea are broad polyphages of deciduous woody plants (Sato 2011; Kim et al. 2016), and our findings of them in nature confirm this. Since the beginning of the 20th century, the species is known also as "Tea Geometrid" – a pest of tea gardens in Japan (Matsumura 1900). "Tea Geometrids" in China are another species – *Ectropis grisescens* Warren, 1894, and *Ectropis obliqua* (Prout, 1915). *M. plumosaria* still presents in some lists of harmful insects (Hill 1987; Biosecurity Australia 2008). However, in recent years, its harmfulness has not been noted in Japan (Sato 2011), and in Korea, this species is rare (Kim et al. 2016). *M. plumosaria* had not been registered in Russia before 1987, but it at once was found in a noticeable number of larvae, which probably suggests an earlier habitation or introduction of this species in the area. However, the moths usually were not recorded in significant numbers up to the present excepting 2003; moreover, during the collection trip in Ryazanovka and Gamov Peninsula on 04-08.X.2012, at the period of the imago of *M. plumosaria*, this species was not observed. This could indicate not favorable environmental conditions for the species in RFE at the extreme northern border of its range lading to large fluctuations in population(s) of *M. plumosaria* here. Nevertheless, the high abundance of the moths in 2021 can indicate a possible improvement in climatic conditions for the development of the species. It is possible that *M. plumosaria* will be able to form episodic outbreaks in SW RFE, which requires monitoring the trends in the distribution and population dynamics of this species.

Subfamily Larentiinae

***Photoscotosia lucicolens* (Butler, 1878)**
(Figs 5–10)

Scotosia lucicolens Butler, 1878: 54, pl. xxxvii. fig. 10 (1878). TL: Japan: Yokohama, Hakodate.

General distribution. Russia (eSW RFE, first record), Japan (Hokkaido, Honshu, Shikoku, Kyushu, Yakushima), S Korea (Nakajima and Yazaki 2011; Kim et al. 2016), China (E Jilin, first record). In BOLD, the specimen of "*Photoscotosia atrostrigata*" from "China, Jilin, Changbaishan North slope, Elevation: 1740 Meters, 42.0675 N, 128.065 E, 2012-06-29, Collectors: Y. Zou" (accession number GWOTL929-13), judging by the photo of the moth, is clearly *Ph. lucicolens*. So, the species is distributed also in NE China, at leas in most eastern Jilin. The report of "*Photoscotosia lucicolens*" from the Sakhalin Island (Beljaev and Mironov 2019: 261) was based on the wrong degemination of aberrant specimen of *Photoscotosia atrostrigata* (Bremer, 1864).

Distribution in RFE. Original records. Primorskii Krai, 34 km SSW of Slavyanka, on the western side of the Gamov Peninsula, Vityaz, 42°35'57.63"N, 31°11'13.78"E, at light, 30.IX.2020, V. Dubatolov leg. – 1♀; ditto, at light, 6-7.X.2021, V.V. Dubatolov leg. – 1♂; ditto, at light, 4-5, 7-8.X.2021, V. Dubatolov leg. – 2♀♀; ditto, at light, 27-30.IX.2021, S.A. Knyazev and S.M. Saikina leg. – 2♂♂, 3♀♀.

Notes. The new locality in Russia is located about 260 km ENE from the place in Jilin. The species is very similar to *Ph. atrostrigata* by appearance, but distinguishable by the heavy widened anterior portion of the postmedial line on the underside of forewing, which looks as blurred blackish blot (Figs 6, 8, 10). In South Korea moths appear twice in June and September-October, somewhat later than *Photoscotosia atrostrigata* (Kim et al. 2016). Larvae are polyphagous on deciduous trees and shrubs, whereas in *Ph. atrostrigata* they are known as oligophagous on Artemisia (Asteraceae) (Nakajima and Yazaki 2011). Thus, there are no trophic obstacles for the naturalization of the species.

***Callabraxas fabiolaria* (Oberthür, 1884)**
(Fig. 2)

Euchera fabiolaria Oberthür, 1884: 35, pl. iii, fig. 3.TL: [China]: Kouy-Tchéou [Guizhou].
Callabraxas fabiolaria: Mironov et al. 2008: 215, 339 (No 7537); Beljaev 2016: 615; Beljaev and Mironov 2019: 264.

General istribution. Russia (eSW RFE), Korea, China (Beijing, Gansu, Zhejiang, Hubei, Hunan, Guangxi, Guizhou, Sichuan, Yunnan, Taiwan) (Xue and Zhu 1999; Kim et al. 2016).

Distribution in RFE. Original records. Primorskii Krai, 36 km SSW of Slavyanka, on the eastern side of the Gamov Peninsula at the southern end of Telyakovsky Bay, 42°34' N, 131°12' E, at light, 30.IX.-1.X.2003, E.A. Beljaev leg. – 1♂ (Mironov et al. 2008); ditto, 20 km SE Ussuriisk, Gornotayozhnoe, 43°41'52.65"N,132°9'29.41"E, at light, 18-22.IX.2021, S.A. Knyazev and S.M. Saikina leg. – 1♂.

Notes. The first location, Gamov Peninsula, distanced about 170 km NE from the nearest known collection place in North Korea – "Shuotsu" [North Hamgyong, Kyongsong] (Bryk 1948), and the second location, Gornotayozhnoe, distanced about 145 km north-east from the Gamov Peninsula. Both specimens are somewhat shabby, that does not allow us to assert the moths are collected near their place of hatching. Nevertheless, we assume current trend to northern dispersion of this species, considering larvae host plant of *C. fabiolaria*, different species of grape (*Vitis*; Vitaceae) (Kim et al. 2016) is common on south of RFE, and that this remarkable moth could hardly be missed during the long history of lepidopterological research in this region.

***Dysstroma cinereata cesa* Koçak & Kemal, 2001**
(Figs 3–4)

Dysstroma cinereata cesa Koçak & Kemal, 2001: 4, nom. nov. pro *japonica* Heydemann, 1929, nec Hori, 1926.
Dysstroma cinereata (Moore, 1867): (Mironov et al. 2008): 215, 339 (No 7475); (Beljaev 2013): 77; (Beljaev 2015): 99; (Beljaev 2016): 617;
Dysstroma cinereata subsp. *japonica*: (Beljaev and Mironov 2019): 265, 387 (No 8935).

General distribution. *D. c. cesa*: Russia (eSW RFE); Japan (Honshu, Shikoku, Kyushu), Korea, ?China (E Jilin). *D. c. cinereata*: China (Hunan, Jiangxi, Sichuan, Yunnan, Taiwan), Nepal, Bhutan, NE India ("Bengal", Sikkim, N West Bengal, Arunachal Pradesh), Myanmar (Prout 1914; Heydemann 1929; Yazaki 1994; Xue and Zhu 1999; Nakajima and Yazaki 2011; Kim et al. 2016; Tóth et al. 2018; Sondhi et al. 2021). Reference of *D. cinereata* from NE China (Zou et al. 2016a, 2016b: supplementary material) need to be verified, as the specimen of "*Dysstroma cinereata*" from "China, Jilin, Changbaishan North slope, Elevation: 1040 meters, 42.2271 N, 128.077 E, 2012-08-10, Collectors: Y. Zou" in the BOLD (accession number GWOTL1040-13), judging by the photo of the moth, is clearly *Paradysstroma corussaria* (Oberthür, 1880).

Figures 1–4. 1 – *Megabiston plumosaria*, male, Vityaz; **2** – *Callabraxas fabiolaria*, male, Gornotayozhnoe; **3, 4** – *Dysstroma cinereata cesa*, females: **3** – Vityaz; **4** – Vladivostok.

Distribution in RFE. Original records. Primorskii Krai, 36 km SSW of Slavyanka, on the eastern side of the Gamov Peninsula at the southern end of Telyakovsky Bay, 42°34' N, 131°12' E, at light, 30.IX.-1.X.2003, E.A. Beljaev leg. – 2♀ (Mironov et al. 2008); *ditto*, 59 km SSW of Slavyanka, Furugelm Island, 42°28'N, 130°55'' E, at light, 17-21.VII.2012, E.A. Beljaev leg. – 1♀ (Beljaev, 2015); Vladivostok suburb, Bogataya Griva ridge, 5 km ESE of Okeanskaya, 240 m above sea level, 43°13'01'' N, 132°03'48'' E, at light, 25.IX.2016, E.A. Beljaev leg. – 1♀; *ditto*, 34 km SSW of Slavyanka, on the western side of the Gamov Peninsula, Vityaz, 42°35'57.63''N, 31°11'13.78''E, at light, 27-30.IX.2021, S.A. Knyazev and S.M. Saikina leg. – 2♀♀.

Notes. The Gamov Peninsula localities of the species in Russia is distanced about 250 km ENE from the nearest collection place of *D. cinereata* in North Korea – Ryanggang Province, Samjiyŏn city, 3.X.1978 (Tóth et al. 2018). Record of the species in the Vladivostok suburb, about 100 km NE from the Gamov Peninsula, could indicate its dispersion to the north, but the single specimen is known from here. At the Telyakovsky Bay the moths were collected nearby the extensive feralled thicket of cultivated common raspberry, *Rubus idaeus* (Rosaceae), which corresponds to the indication *Rubus* as the larvae host plant for the species (Nakajima and Yazaki 2011). Specimens from Vityaz and Vladivostok suburb were collected in areas of broad-leaved forest near country cottages where the raspberry is usually cultivated. In addition to the culture raspberry, the only native raspberry associated with glades in the broad-leaved forest, *Rubus crataegifolius*, would be potential host plant for *D. cinereata* in S RFE. Observation of the moth in Furugelm Island, where *R. idaeus* absents and *R. crataegifolius* presents (Gorovoi and Boyko 1981) supports this assumption. However, sparse distribution of the *R. crataegifolius*, which usually does not form dense thicket, could hamper spread of the species in the south of RFE.

The subspecies *D. c. cesa* (=*D. c. japonica*, see below) was described as a separate species outwardly well-defined from *D. cinereata* (Heydemann 1929; Prout 1938). Later probably Inoue (1977) first subordinated *cesa* (as *japonica*) to *D. cinereata* as subspecies without comments. Choi (2004) supported this by referring to the negligible genitalic differences are at the species level between them. Nevertheless, considering the difference in appearance, probably separate areas and high similarity of the genitalia among many species of *Dysstroma*, taxonomic status of *D. c. cesa* needs to be tested molecularly.

Nomenclature notes. Heydemann (1929), revising the *Dysstroma* Hübner, 1825, in the title and in the text clearly states, that he accepts the name *Dysstroma* as subgenus of the genius *Cidaria* Treitschke, 1825. However, in the text he never used trinomen *Cidaria* (*Dysstroma*) sp., only binomen *D.*[*ysstroma*] sp., or only species name without indication of genus name. This causes confusion when quoting the original combinations of the names of Heydemann's nominal taxa. In the Catalogue "Geometrid Moths of the World" (Parsons et al. 1999) all new names from Heydemann (1929) are combined with *Cidaria*. But, in Hausmann and Viidalepp (2012), all primary Heydemann's names are combined with *Cidaria* excepting the "*Dysstroma pseudimmanata* Heydemann, 1929" (loc. cit.: 281). In Kim et al. (2016) origi-

nal Heydemann's names are given as "*Cidaria korbi* Heydemann, 1929" (loc. cit.: 385) and "*Dysstroma japonica* Heydemann, 1929" (loc. cit.: 385). Historically, Inoue (1977, 1982), judging from the absence of parentheses enclose the author and the year of taxon description, accept *Dysstroma* as generic name for Heydemann's taxa. Subsequently, same was accepted by Viidalepp (1996), Xue and Zhu (1999), Nakajima and Yazaki (2011), Beljaev (2016), and Beljaev and Mironov (2019), which has to be considered as incorrect nomenclature. As the right original combination is [*Cidaria*] (*D.*[*ysstroma*]) *japonica* Heydemann, 1929, this name is an objective homonym of *Cidaria corydalaria* var. *japonica* Hori, 1926. Accordingly, Koçak, Kemal (2001: 4) correctly proposed a replaced name, *Dysstroma cinereata* ssp. cesa Koçak & Kemal, 2001, for *japonica* Heydemann, 1929, but it was totally neglected in literatures before the present as a result of widely accepted wrong treatment of Heydemann's names.

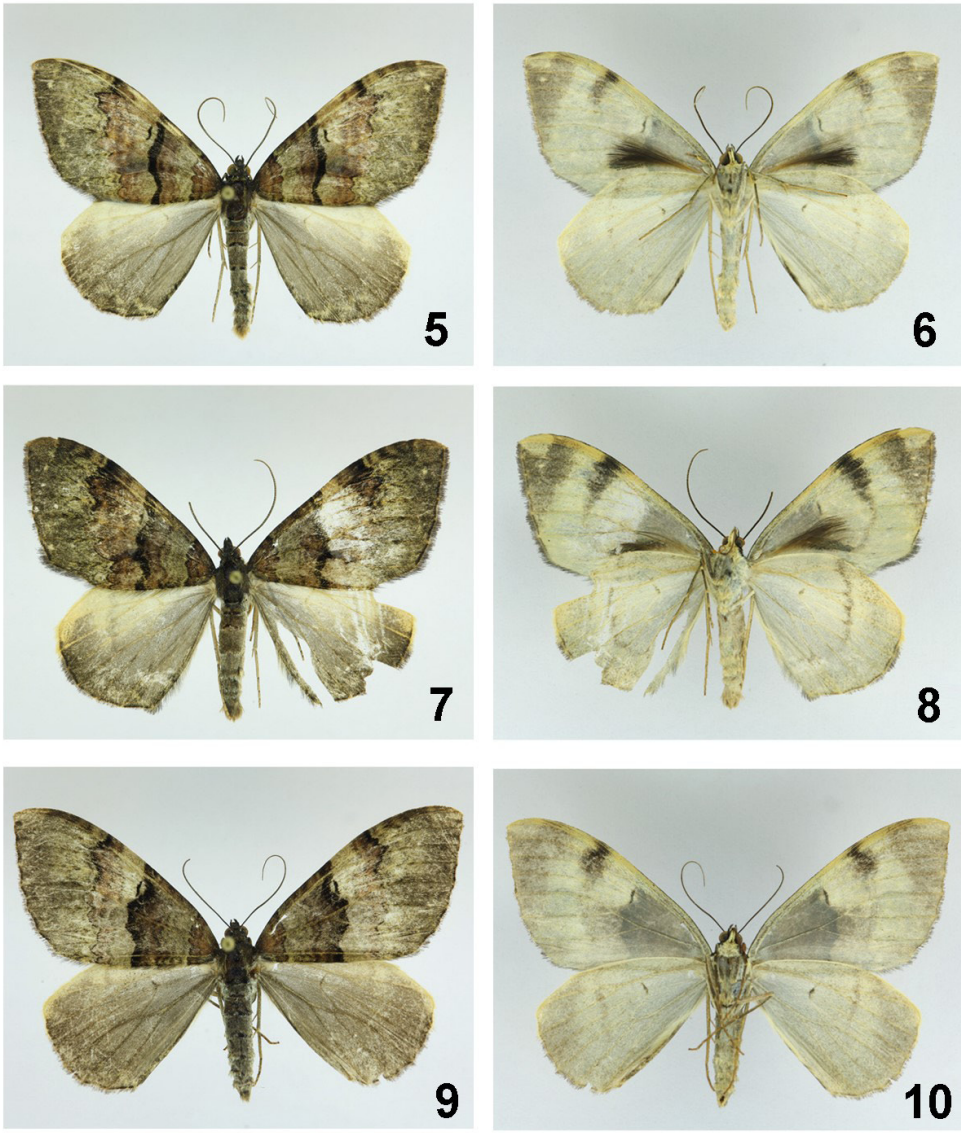
Discussion

Trends to penetration of southern moth into RFE start to be observed from registration on eSW RFE of Sphingidae – remarkable moths which hardly be loosed by insert collectors. There are *Clanis undulosa* Moore, 1879 – first records in 1975, 1979 (Dubatolov 1982, 2021), *Acosmeryx naga* (Moore, [1858]) – first record in 2002 (Beljaev 2003), and *Ambulyx tobii* (Inoue, 1976) – first record in 2011 (Koshkin and Bezborodov 2013), which to the present reached south of Khabarovskii Krai, i.e. territory placed 4-6° (~ 440-660 km) north from locations of first observations (Koshkin et al. 2021). These species successively naturalized in the continental south of RFE. There are a number of observations of other southern sphingids and noctuids (Nolidae, Erebidae, and Noctuidae) in RFE (Dubatolov 2021). As they are usually single observed and belong to families with moths being active and powerful flyers, most of them are probably episodic immigrants penetrating mainly from the Korean Peninsula along the coast of Japan / East Sea, including by means of typhoon transfer (Beljaev and Velyaev 2016).

As to geometrids, these moths represent an ideal large group of Macrolepidoptera for biogeographic studies due to their high taxonomic diversity, wide ecological diversification combined with usually close association with their typical habitats and low migratory activity, as well as relatively easy detection in nature (Holloway 1986; Beljaev 2011). However, their reaction to the current climatic trend das not explored in RFE, and considering the spatial conservatism of geometrids, it should be assumed that they change their species ranges along with the climatic trends more slowly than migratory active taxa of moths and butterflies, and so they provide more reliable markers of biocenotic modifications.

Regarding the species treated here, *Ph. lucicolens*, first discovered in 2020, is apparently in the process of naturalization in RFE. *M. plumosaria* probably naturalized in the RFE before 1987, and it is currently showing an increase in abundance.

Probably, this species undergoes biological progress here, but so far, the data about the expansion of its range to the north is lacking. *D. cinereata* and *C. fabiolaria*, both first observed in 2003, probably also naturalized, and currently are moving northward. Judging from the singular founds, the rate of expansion of the geometrids could be estimated very preliminary as ~ 1° per 10-15 years, which is 3-4 times slower than these of sphingids. Thus, the geometrid moths, along with some hawk moths, definitely show a trend towards the northern expansion of their ranges in the RFE, but at a much slower rate.



Figures 5–10. *Photoscotosia lucicolens*, Vityaz: **5–8** – males, **9–10** – females (**5**, **7**, **9** – upper side; **6**, **8**, **10** – under side).

Conclusion

As a result of this investigation, *Ph. lucicolens* is recorded from Russia and China (Jilin) for the first time, for *M. plumosaria*, *C. fabiolaria*, and *D. cinereata* naturalization and northern spreading in RFE are accepted. Supposedly, the rate of northern expansion of the geometrids is 3-4 times slower than these of sphingids. The potential harmfulness of *M. plumosaria* in RFE is assumed. The presence of *D. cinereata* in Jilin is questioned. The validity of the nominal name *Dysstroma cinerea cesa* Koçak & Kemal, 2001, is substantiated.

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