Discovery of Nemophora chrysoprasias Meyrick (Lepidoptera: Adelidae) from China, with notes on its related species

Hirowatari, Toshiya
Entomological Laboratory, Kyushu University, Faculty of Agriculture

Yagi, Sadahisa
Entomological Laboratory, Kyushu University, Faculty of Agriculture

Liao, Cheng-Qing
Hunan Provincial Key Laboratory for Biology and Control of Plant Diseases and Insect Pests, Hunan Agricultural University

Huang, Guo-Hua
Hunan Provincial Key Laboratory for Biology and Control of Plant Diseases and Insect Pests, Hunan Agricultural University

他

出版情報：Journal of Asia-Pacific Biodiversity. 15 (3), pp.391-400, 2022-09-01. Elsevier
バージョン：

Journal of Asia-Pacific Biodiversity 15 (2022) 391–400

Contents lists available at ScienceDirect

Journal of Asia-Pacific Biodiversity

journal homepage: http://www.elsevier.com/locate/japb

Original Article

Discovery of *Nemophora chrysoprasias* Meyrick (Lepidoptera: Adelidae) from China, with notes on its related species

Toshiya Hirowatari [a,*], Sadahisa Yagi [a], Cheng-Qing Liao [b], Guo-Hua Huang [b], Min Wang [c]

[a] Entomological Laboratory, Kyushu University, Faculty of Agriculture, 744 Motooka, Nishi-ku, Fukuoka, 819-0395, Japan
[b] Hunan Provincial Key Laboratory for Biology and Control of Plant Diseases and Insect Pests, Hunan Agricultural University, Changsha, Hunan 410128, PR China
[c] Department of Entomology, South China Agricultural University, Guangzhou 510640, Guangdong, China

ARTICLE INFO

Article history:
Received 23 February 2022
Received in revised form
20 April 2022
Accepted 21 April 2022
Available online 7 May 2022

Keywords:
Adelidoidea
genitalia
Nemophora rubrofascia
new record
Yunnan

ABSTRACT

Nemophora chrysoprasias (Meyrick, 1907), previously known only by the type series from Assam, India, was discovered in the Yunnan Province of China. This study is the first to illustrate the male and female genitalia of *N. chrysoprasias*. Despite their differing appearances, this species is determined to be related to *N. rubrofascia* Christoph, 1882 based on their morphological characters and DNA barcode sequences.

Introduction

The genus *Nemophora* includes approximately 350 species, among which approximately 150 species remain undescribed (Kozlov 2004). In China, including Taiwan, more than 40 species of the genus have been recorded (Heppner 1992; Kozlov 1997; Kozlov and Hirowatari 1997; Wang et al. 2000; Hua 2005; Hirowatari et al. 2012). During our joint research, we collected a beautiful adelid moth by light trap in the Yunnan Province of China. Based on its unique wing markings, the moth was later identified as *Nemophora chrysoprasias* (Meyrick, 1907), which was previously only known by the type series from Assam, India. This is the first article to discuss the phylogenetic position of this species. In this article, we inferred the related *Nemophora* species by examining the male and female genitalia and DNA barcode sequences, comparing these observations with those of *N. paradisea* (Butler, 1881), *N. smaragdaspis* (Meyrick, 1924), and *N. rubrofascia* (Christoph, 1882). Additionally, we briefly reviewed the host plants of the related species to determine the unknown host plant of *N. chrysoprasias*.

Material and methods

Specimens of *N. chrysoprasias* reported in this study were collected from field surveys conducted in Midu (2350 m) (Figure 6) and Weixi (2150 m) in the Yunnan Province of China between July 2016 and July 2018, respectively. Male and female genitalia were observed under a stereoscopic microscope (Zeiss Stemi 305) after specimen abdomens were macerated for approximately 5 min in 10% KOH, heated in a boiling water bath, and preserved in glycerin. In order to detect the phylogenetic position of *N. chrysoprasias*, several morphological characteristics, including wing markings, antennae, and male and female genitalia, were compared with those of *N. paradisea*, *N. smaragdaspis*, and *N. rubrofascia*.

The terminology for morphological characteristics follows that of Nielsen (1985) and Davis (1999). For comparing eye sizes, the eye size index detailed by Hirowatari (1997), that is, "horizontal eye diameter (hd)/minimum distance between eyes in dorsal view (md)", and the interocular index detailed by Davis (1975), that is, "vertical eye diameter (vd)/interocular distance (id)", were calculated.

DNA analysis

Some collected specimens, including those of *N. smaragdaspis*, *N. paradisea*, and *N. rubrofascia*, were used for DNA extraction in the

* Corresponding author. Tel.: +92 802 4572.
E-mail address: hirowat_t@agr.kyushu-u.ac.jp (T Hirowatari)
Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

https://doi.org/10.1016/j.japb.2022.04.009

Table 1. Sample IDs for specimens used in the molecular phylogenetic analysis.

Species name	Sample ID	Genbank accession number	sex	Location	References (Depository)
Nemophora chrysoprasias	SaY456	ON256892	male	China, Yunnan	This study (HUNAU)
Nemophora chrysoprasias	SaY540	ON256891	female	China, Yunnan	This study (HUNAU)
Nemophora ruburofascia	SaY541	ON256890	male	Japan, Fukuoka Pref.	This study (ELKU)
Nemophora smaragdaspis	SaY441	ON256889	male	Japan, Fukuoka Pref.	This study (ELKU)
Nemophora pfeifferella	TLMF Lep 05723	-	-	France, Provence-Alpes-Cote d'Azur	Mutanen et al. (2016)
Nemophora metallica	TLMF Lep 08014	KM573376	-	Austria, Vorarlberg	Huemer et al. (2014)
Nemophora metallica	MM06620	HM873371	male	Finland, Karelia borealis	Huemer et al. (2014)
Nemophora raddaella	TLMF Lep 05718	-	-	France, Provence-Alpes-Cote d'Azur	Mutanen et al. (2016)
Nemophora violellus	BC ZSM Lep 61478	KX047171	male	Germany, Bavaria	Mutanen et al. (2016)
Nemophora istrianellus	KBE 2018191	-	-	Croatia, Zadar County	-
Nemophora cupriacella	MM19243	JF854548	-	Finland, Karelia australis	Mutanen et al. (2016)
Nemophora cupriacella	BC ZSM Lep 37770	HQ563611	female	Germany, Bavaria	Mutanen et al. (2016)
Nemophora associatella	TLMF Lep 07696	KP253632	-	Austria, Vorarlberg	Mutanen et al. (2016)
Nemophora associatella	BC ZSM Lep 29144	KX040386	male	Germany, Bavaria	Mutanen et al. (2016)
Nemophora staudingerella	MF051817	MF051817	-	-	-
Nemophora chalybeella	JCS-06-0140	KF523808	-	South Korea, Mt. Weolaksan	-
Nemophora chalybeella	SWC-07-2033	KF523807	-	South Korea, Chungbuk, Jecheon	-
Nemophora degeerella	RMNH.INS.540689	KX048634	-	Netherlands, South Holland	Mutanen et al. (2016)
Nemophora degeerella	RMNH.INS.540936	KX049191	-	Netherlands, South Holland	Mutanen et al. (2016)
Nemophora scopolii	BC ZSM Lep 25763	GU707081	male	Germany, Bavaria	Mutanen et al. (2016)
Nemophora scopolii	TLMF Lep 09246	KX061985	-	Austria, Tyrol	Mutanen et al. (2016)
Nemophora congruella	BC ZSM Lep 26940	HM902043	male	Germany, Bavaria	Mutanen et al. (2016)
Nemophora congruella	TLMF Lep 17829	-	-	Austria, Tyrol	Huemer and Hebert (2016)
Nemophora ochsenheimerella	BC ZSM Lep 25108	HM422129	female	Germany, Bavaria	Mutanen et al. (2016)
Nemophora ochsenheimerella	MM19346	JN261650	-	Denmark, Sj	Mutanen et al. (2016)
Nemophora bellela	MM04142	HM386929	-	Finland, Lapland	Mutanen et al. (2016)
Nemophora bellela	MM18063	JF854097	-	Finland, Lapponia inarensis	Mutanen et al. (2016)
Nemophora amatella	MM10115	HM874582	-	Finland, Ostrobottnia ouluensis	Mutanen et al. (2016)
Nemophora amatella	MM15510	HM876309	female	Finland, Regio kuusamoensis	Mutanen et al. (2016)
Nemophora prodigellus	TLMF Lep 09886	KP253558	-	Austria, Vorarlberg	Huemer and Hebert (2015)
Nemophora minimella	TLMF Lep 12520	-	-	Austria, Vorarlberg	-
Nemophora minimella	TLMF Lep 05344	-	-	Macedonia, Mavrovo National Park	Mutanen et al. (2016)
Nemophora fasciella	TLMF Lep 05722	-	-	France, Provence-Alpes-Cote d'Azur	Mutanen et al. (2016)
Nemophora dumerilella	BC ZSM Lep 37555	KX040946	male	Germany, Bavaria	Mutanen et al. (2016)
Nemophora topazias	10ANIC-02708	JF840363	-	Australia, New South Wales	Hebert et al. (2013)
Nemophora topazias	10ANIC-02709	JF840364	-	Australia, New South Wales	Hebert et al. (2013)
Nemophora chrysolamprella	10ANIC-02710	HQ922254	-	Australia, New South Wales	Hebert et al. (2013)
Nemophora opalina	ANIC Gen No. 001860	-	-	Australia, Queensland	-
Nemophora brachypetala	10ANIC-02705	KF391052	-	Australia, Queensland	Hebert et al. (2013)
Nemophora panaeola	ANIC Gen No. 000877	-	-	Australia, Queensland	-
Adela purpurea	09PROBE-09420	HM375675	-	Canada, Churchill	Hebert et al. (2016)
Cauchas cyanella	09PROBE-09626	HM430271	-	Canada, Churchill	Hebert et al. (2016)
Nematopogon metaxella	TLMF Lep 12481	KP253419	-	Austria, Vorarlberg	Huemer and Hebert (2015)

Figure 1. *Nemophora chrysoprasias* (Meyrick) from Yunnan, China: A, Male; B, Female; C, Head and thorax, dorsal view, male; D, Ditto, female.

Entomological Laboratory at Kyushu University, Fukuoka, Japan, (ELKU) and the Hunan Agricultural University, Changsha, China (HUNAU) (Table 1). DNA was extracted from the abdomen of each specimen using the DNeasy Blood & Tissue Kit (Qiagen) following manufacturer protocols. We amplified a barcode region of the mitochondrial COI (cytochrome c oxidase subunit 1) gene (658 bp) using the primer set LepF1+LepR1 (Hebert et al. 2004) and a DNA polymerase: KOD One® PCR Master Mix, Blue (TOYOBO CO., LTD.). The PCR amplification was performed as follows: 38 cycles at 98 °C for 10 s, 50 °C for 5 s, and 68 °C for 5 s. DNA of *N. paradisea* was fragmented and the amplicons were unobtainable; however, the amplicons of the other species were purified using ExoSAP-IT™ Express (Thermo Fisher Scientific Inc., USA), and then sequencing was carried out by the Sanger Sequencing services (Genewiz, USA).

The obtained sequences were aligned manually using MEGA 7.0.26 to ensure no ambiguities or indels were present (Kumar et al. 2016). The sequences of the genus *Nemophora* and outgroup sequences were then obtained from Boldsystems (https://www.boldsystems.org/) and added to our data (Table 1). Sequence alignment was carried out with MAFFT v7.222 (Katoh and Sandley 2013) using the accurate alignment method L-INS-i. Pairwise sequence distances were calculated using MEGA 7.0.26 (Kumar et al. 2016) with the Kimura 2-parameter model (K2P) and p-distance. Due to the heterogeneity of the 3rd codon of COI barcode regions, this partition was binarized (RY coding) for constructing the phylogenetic tree. The phylogenetic construction analyses by maximum parsimony and maximum likelihood analyses were performed as described by Hirowatari et al. (2021).

Results

Systematic accounts

Nemophora chrysoprasias (Meyrick)
(Figures 1–4)

Nemotois chrysoprasias Meyrick, 1907: 992. [Holotype examined] NMH; Meyrick, 1912a: 8; Meyrick, 1912b: 133, f.1.

Specimens examined. 1♂1♀, Bailongtan, Midu (2,350 m), Yunnan, China, 23 vii 2016, LT, (GH Huang & M Wang). HUNAU; 1♀, Weixi (2150 m), Yunnan, China, 24 vii 2018, (SF Mo & ZP Miao) HUNAU.

Distribution. India (Assam), China (Yunnan) (new record).

Male (Figure 1A). Forewing 10.3 mm; wing expanse 22.0 mm (n=1).

Head (Figures 1C and 2A). Vertex with raised yellow hairs sparsely mixed with dark brown hairs; face covered with smooth bronzy scales with golden luster, lateral part along eyes with yellow hairs dorsally and yellow scales ventrally. Eyes large, closely approximated dorsally; eye size index: ca. 8.7, interocular index ca. 1.3. Maxillary palpus thin and short with yellow scales, 0.4× length of labial palpus. Labial palpus 0.7× vertical eye diameter, pale yellow mixed with long dark brown hairs. Antenna 28.2 mm, 2.7× forewing length; basal 1/7 blackish brown, scarcely with black raised scales basally, basal 2/7–3/7 and apical parts silvery white, other most parts ringed with silvery white and light bronze. Legs (Figure 2C): fore and mid legs: femur and tibia bronze with metallic green tinge, tarsus white ringed with dark brown; hind leg: femur silvery white, tibia white with long raised white hairs dorsally and ventrally ringed with dark brown distally, tarsus white to light brown ringed with white to pale brown. Tegula and thorax metallic green. Forewing basal 1/4 metallic green; a transverse orange fascia broad, margined with silvery-leaden fasciae which are narrowly boarded with black; distal 1/3 metallic green scattered with black scales near silvery-leaden fasciae; cilia dark brown. Hindwing entirely white and semitransparent except dark brown near apex; cilia white except dark brown near apex; frenulum consisted of a single long and stout bristle.

Female (Figure 1B). Forewing 9.6 mm; wing expanse 19.3 mm (n=1).

Head (Figures 1D and 2B). Vertex with raised pale yellow hairs, sparsely mixed with brown hairs; face bald (scales likely lost), lateral part along eyes with pale yellow scales. Eyes small, eye size index: approximately 0.8, interocular index ca. 0.8. Maxillary palpus thin and short with yellow scales, 0.3× length of labial palpus. Labial palpus 1.2× vertical eye diameter, pale yellow mixed with short dark brown hairs. Antenna 8.4 mm, approximately 0.9×

Figure 2. Head and thorax of *Nemophora chrysoprasias* (Meyrick): A and B, Head, ventro-lateral view (arrow indicates frenulum); C and D, Head and thorax showing legs, ventro-lateral view; A and C, Male; B and D, Female.

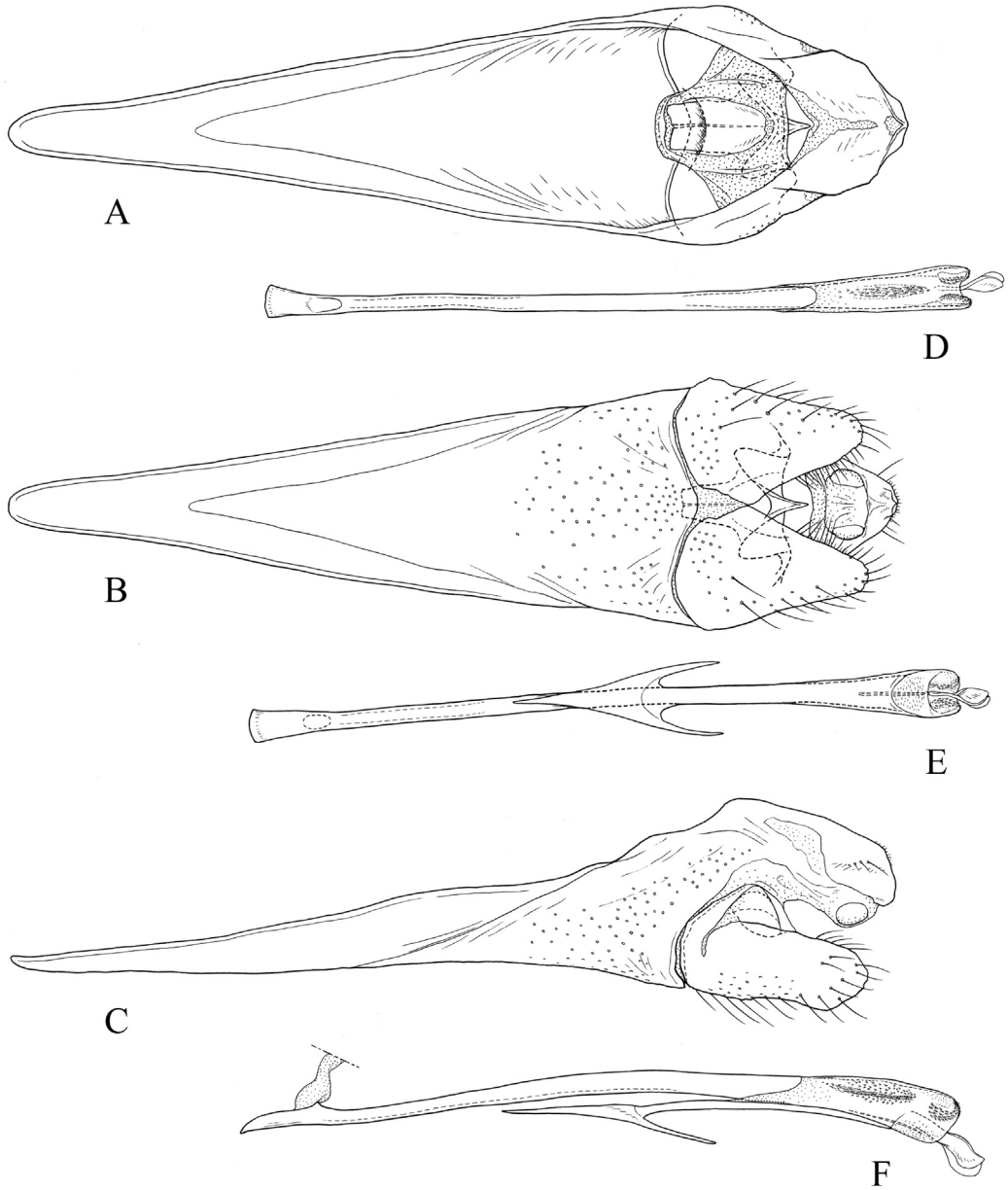

Figure 3. Male genitalia of *Nemophora chrysoprasias* (Meyrick): A, Whole genitalia except phallus (dorsal view); B, Ditto (ventral view); C, Ditto (lateral view); D, Phallus (dorsal view); E, Ditto (ventral view); F, Ditto, (lateral view).

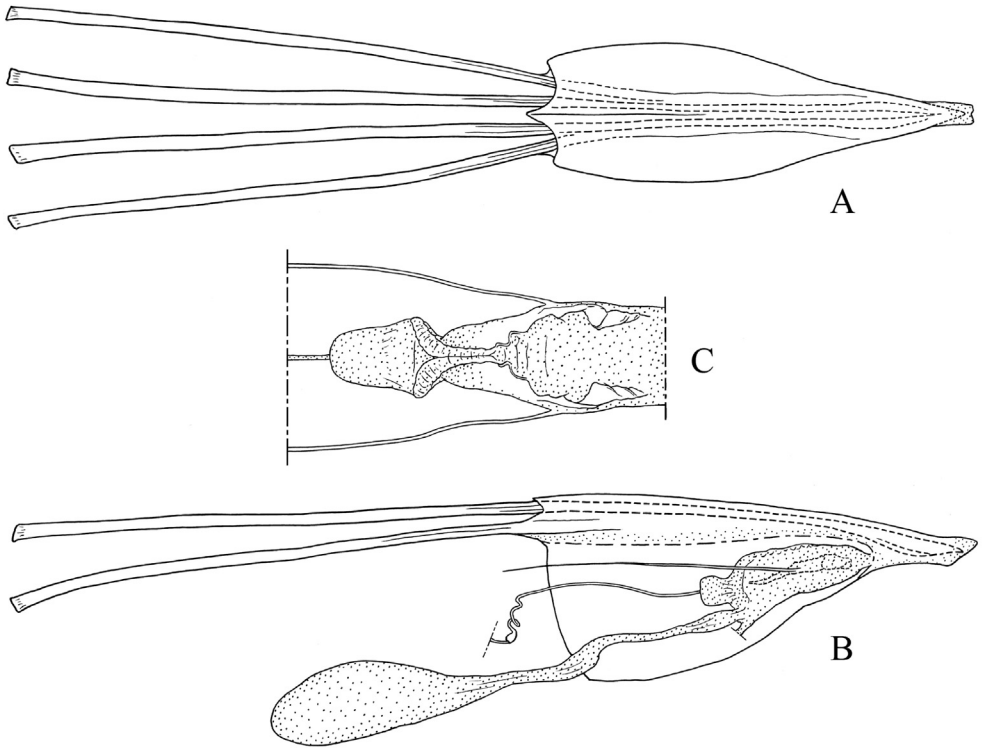

Figure 4. Female genitalia of *Nemophora chrysoprasias* (Meyrick): A, Terminalia (dorsal view); B, Ditto (lateral view); C, Vestibulum (dorsal view).

forewing length; basal 1/2 dark brown, thickened with raised dark brown scales medially; distal 1/2 irregularly ringed with silvery white and light bronze, smooth, and slender. Legs (Figure 2D) similar to male. Tegula and thorax metallic green. Wing markings similar to male; hindwing with frenulum consist of six short and thin bristles.

Male genitalia (Figure 3). Uncus short with a weak median keel. Vinculum long approximately 3.6× as long as valva. Valva triangular in ventral view, subquadrate in lateral view, rounded apically; sacculus produced anteriorly to form suspensorium for phallus; suspensorium trapezoid, anterior part slightly beyond posterior margin of vinculum in ventral view. Transtilla wide medially and narrow laterally near valva; median process short, pointed. Phallus long and slender, nearly straight, weakly curved dorsally at middle; terminal part with a petal-like lamellate process; manica, a pair of patches of minute spines dorsally; vesica dorsally with cornuti consisting of a row of minute spines. Juxta arrow-shaped; arrowhead and lateral arms long and narrow, pointed.

Female genitalia (Figure 4). Apophysis posterioris and apophysis anterioris long and slender. Vestibulum with cup-like sclerotization with frills medially, a pair of sclerites near attachment point of guy wire; median part with bifurcate winkled lip-like membrane dorsally. Bursa copulatrix relatively long and membranous.

Host plant. Unknown.

DNA analysis

The male *N. chrysoprasias* specimen (SaY456) showed 5 bp differences (p-distance, 0.8%) from the female specimen (SaY540) in the COI barcoding region (Table 2). The two *N. chrysoprasias* specimens showed 8.1% and 8.5% pairwise distances from the *N. rubrofascia* specimen (SaY541). These interspecific distances were slightly smaller than the pairwise distances of *N. chrysoprasias* from *N. smaragdaspis* (8.5% and 9.0%, respectively). From the phylogenetic analysis, *N. chrysoprasias* and *N. rubrofascia* appeared as monophyletic with a relatively high bootstrap value (83%) though DNA barcode sequences is insufficient to clarify the phylogenetic relationship in general (Figure 5). Thus, the pairwise distances and obtained phylogenetic tree suggested a close relationship between *N. chrysoprasias* and *N. rubrofascia* rather than *N. smaragdaspis*.

Discussion

Nemophora chrysoprasias is easily distinguishable from other congeners by its unique metallic green wing markings with a transverse orange fascia in the forewings and semitransparent white ground color except dark brown near the hindwing apex. This species may be externally similar to *N. paradisea* and *N. smaragdaspis* in having a transverse orange fascia in the forewing; however, in this study, *N. chrysoprasias* was found to be more closely related to *N. rubrofascia* with a transverse red fascia in the forewing judging from several characteristics. (1) In the male genitalia, the vinculum is very long (approximately 3.6 times as long as the valva) and the terminal part of the phallus has a petal-like lamellate process in *N. chrysoprasias* and *N. rubrofascia*, whereas the vinculum is moderate in length (approximately 2.5 times as long as the valva). Additionally, a pair of strongly sinuate hooks is present dorsally near apex in *N. paradisea* and *N. smaragdaspis* (Hirowatari and Yamamoto 2004). (2) In the female genitalia, the vestibulum has a cup-like sclerotization, a pair of sclerites near the guy wire attachment point, and a median part with a bifurcate membrane dorsally in *N. chrysoprasias* and *N. rubrofascia*, whereas they are absent in *N. paradisea* and *N. smaragdaspis*. (3) In the wing markings, sexual dimorphism is not present in *N. chrysoprasias* and *N. rubrofascia*, whereas the basal part of the female wing color is different from that of male in *N. paradisea* and *N. smaragdaspis*. (4) The basal part of the antenna is

Table 2. Intraspecific and interspecific pairwise K2P distances (lower left) and p-distances (upper right) in the COI barcode region. The top 18 samples similar to *N. chrysoprasias* are shown. Within sample names, sample IDs are shown before species names.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	SaY456_*Nemophora_chrysoprasias*_male_China		0.008	0.085	0.090	0.070	0.074	0.071	0.076	0.078	0.078	0.080	0.086	0.088	0.085	0.089	0.093	0.093	0.093
2	SaY540_*Nemophora_chrysoprasias*_female_China	0.008		0.081	0.085	0.071	0.076	0.076	0.081	0.079	0.076	0.079	0.086	0.083	0.082	0.086	0.090	0.090	0.088
3	SaY541_*Nemophora_rubrofascia*_Fukuoka	0.091	0.086		0.085	0.078	0.081	0.088	0.090	0.087	0.075	0.079	0.089	0.077	0.102	0.105	0.093	0.093	0.084
4	SaY441_*Nemophora_smaragdaspis*_Fukuoka	0.096	0.091	0.090		0.065	0.058	0.074	0.070	0.067	0.056	0.057	0.073	0.069	0.075	0.074	0.065	0.065	0.062
5	TLMF Lep 05718_*Nemophora_raddaella*	0.074	0.075	0.082	0.069		0.038	0.049	0.050	0.041	0.040	0.041	0.048	0.066	0.078	0.082	0.074	0.074	0.064
6	KBE 2018191_*Nemophora_istrianellus*	0.078	0.080	0.085	0.061	0.039		0.052	0.051	0.044	0.017	0.022	0.051	0.063	0.073	0.073	0.071	0.071	0.062
7	MM06620_*Nemophora_metallica*	0.075	0.080	0.094	0.079	0.051	0.054		0.017	0.052	0.058	0.061	0.058	0.077	0.083	0.086	0.084	0.084	0.074
8	TLMF Lep 08014_*Nemophora_metallica*	0.080	0.086	0.096	0.074	0.052	0.053	0.017		0.056	0.055	0.057	0.056	0.080	0.086	0.089	0.088	0.088	0.078
9	TLMF Lep 05723_*Nemophora_pfeifferella*	0.082	0.084	0.092	0.070	0.042	0.046	0.054	0.059		0.043	0.046	0.056	0.059	0.072	0.071	0.070	0.070	0.050
10	MM19243_*Nemophora_cupriacella*	0.082	0.081	0.079	0.059	0.041	0.018	0.061	0.057	0.044		0.005	0.046	0.063	0.072	0.073	0.075	0.075	0.061
11	BC ZSM Lep 37770_*Nemophora_cupriacella*	0.085	0.083	0.083	0.059	0.042	0.023	0.065	0.059	0.047	0.005		0.051	0.064	0.074	0.074	0.079	0.079	0.063
12	BC ZSM Lep 61478_*Nemophora_violellus*	0.092	0.092	0.095	0.077	0.050	0.054	0.061	0.059	0.059	0.048	0.054		0.074	0.083	0.086	0.078	0.078	0.071
13	BC ZSM Lep 37555_*Nemophora_dumerilella*	0.094	0.088	0.081	0.072	0.069	0.065	0.081	0.085	0.062	0.065	0.067	0.078		0.069	0.068	0.066	0.066	0.042
14	BC ZSM Lep 29144_*Nemophora_associatella*	0.090	0.087	0.110	0.080	0.083	0.077	0.088	0.092	0.076	0.076	0.078	0.088	0.072		0.003	0.078	0.078	0.058
15	TLMF Lep 07696_*Nemophora_associatella*	0.095	0.091	0.113	0.079	0.087	0.077	0.091	0.095	0.075	0.077	0.079	0.092	0.071	0.003		0.076	0.076	0.057
16	MM10115_*Nemophora_amatella*	0.099	0.096	0.099	0.068	0.078	0.075	0.089	0.094	0.073	0.079	0.083	0.082	0.069	0.083	0.080		0.000	0.061
17	MM15510_*Nemophora_amatella*	0.099	0.096	0.099	0.068	0.078	0.075	0.089	0.094	0.073	0.079	0.083	0.082	0.069	0.083	0.080	0.000		0.061
18	TLMF Lep 05722_*Nemophora_fasciella*	0.099	0.094	0.089	0.065	0.067	0.064	0.079	0.082	0.052	0.064	0.066	0.075	0.043	0.060	0.059	0.063	0.063	

Figure 5. Maximum likelihood tree based on the COI sequences by RaxML 8 (Stamatakis 2014) with 1000 bootstrap replicates. Branch lengths are proportional to ML estimated genetic distances. Numbers associated with branches indicate bootstrap values higher than 50% (ML/MP). Within sample names, sample IDs are shown before species names. The Genbank accession number is also shown after species names. ML, maximum likelihood; MP, maximum parsimony.

smooth in *N. chrysoprasias* and *N. rubrofascia,* but is covered with raised scales in *N. paradisea* and *N. smaragdaspis* in both sexes.

This close relationship of *N. chrysoprasias* and *N. rubrofascia* was also congruent with the analysis based on DNA barcode sequences as previously detailed. In the Lepidopterorum Catalogus, Meyrick (1912a) listed "*Nemotois chrysoprasias*" next to "*Nemotois rubrifasia* (=*rubrofascia*)". This may indicate that Meyrick had the insight to see the close relationship of these two species. Additionally, the close relationship of *N. chrysoprasias* and *N. rubrofascia* also suggests that the latter species distributed in eastern Asia (far eastern Russia, eastern China, and Japan) originated from the Himalayan region.

As for the biology, Adelidae moths are known to oviposit eggs into plant tissues that the young larvae feed on, while the later instars move down to the ground making a portable case and feed on dead plant material. More than 20 families of these plants are known as their hosts (ovipositing plant), and the parts of the plants to which the females oviposit vary, such as midribs or petioles of leaves, stalks/stems, flower buds, or ovaries (Chapman 1891, 1892; Kuroko 1961, Heath and Pelham-Clinton 1976; Bland 1977; Küppers

Figure 6. Habitat of *Nemophora chrysoptrasias* in Midu, Yunnan, China: A. Light trap; B-D, Vesitation around the light trapping site.

1980; Hirowatari and Yamanaka, 1996; Sasaki et al. 2017). Although the host plant of *N. chrysoprasias* is unknown, females of the related species were reported to oviposit eggs into the flower buds of the following herbs in Japan: *N. rubrofascia*: *Lysimachia clethroides* (Primulaceae) (Mori 1992), *N. paradisea*: *Patrinia villosa* (Valerianaceae) (Hirowatari and Nagaike 1998), and *N. smaragdaspis*: *Lespedeza bicolor* (Fabaceae) (Murata and Shigenaga 2018). Judging from this information about the related species, *N. chrysoprasias* females probably oviposit eggs into flower buds of similar herbs; however, further studies are required to clarify the phylogenetic relationships and the life history and evolution of the host plant use in *Nemophora chrysoprasias* and its related species.

Declaration of competing interest

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

Acknowledgments

The authors would like to thank Kevin Tuck (the National History Museum, London) for allowing the first author to examine the lectotype of *N. chrysoprasias*. Issei Ohshima (Kyoto Prefectural University), Naomichi Ohara (ELKU), and Miao Zhipeng (South China Agricultural University) supported the survey in Yunnan. Kimitaka Sasaki (Fukuoka, Japan) provided us with some Japanese local literatures. This study was supported by the National Natural Science Foundation of China [grant number 32111540167] and the Biodiversity Survey and JSPS KAKENHI [grant number JP16H05766].

References

Bland KP. 1977. Note on the biology of the genus *Adela* (Lepido.: Incurvariidae). *Proceeding and Transactions of the British Entomological and Natural History Society* 10:88–91.
Chapman TA. 1891. Notes on the life-history of *Adela rufimitrella*. *Entomologist's Monthly Magazine* 27 (2nd ser. 2):191–193.
Chapman TA. 1892. Oviposition of *Adela viridella*. *Entomologist's Monthly Magazine* 28 (2nd ser. 3):42–44.
Davis DR. 1975. West Indian moths of the family Psychidae with descriptions of new taxa and immature stages. *Smithsonian Contribution to Zoology* 188:1–66.
Davis DR. 1999. The monotrysian Heteroneura (Incurvariidae). In: Kristensen NP, editor. *Lepidoptera, Moths and Butterflies 1, Handbook of Zoology*. Berlin & New York: Walter de Gruyter. pp 65–90.
Heath J, Pelham-Clinton EC. 1976. Incurvariidae. In: Heath, editor. *The moths and butterflies of Great Britain and Ireland*. London: The Curwen press. pp 277–300.
Heppner JB. 1992. Adelidae. In: Hepnner JB, Inoue H, editors. *Checklist. Lepidoptera of Taiwan*, 1. Gainesville: Scientific Publishers Inc. p 63 (2).
Hebert PDN, Penton EH, Burns JM, et al. 2004. Ten species in one: DNA barcoding reveals cryptic species in the neotropical skipper butterfly *Astraptes fulgerator*. *Proceedings of the National Academy of Sciences* 101 (41):14812–14817.
Hebert PDN, deWaard JR, Zakharov EV, et al. 2013. A DNA 'Barcode Blitz': Rapid Digitization and Sequencing of a Natural History Collection. *PLoS One* 8 (7): e68535.
Hebert PDN, Ratnasingham S, Zakharov EV, et al. 2016. Counting animal species with DNA barcodes: Canadian insects. *Philosophical Transactions of the Royal Society B* 371 (1702):1–10.
Hirowatari T. 1997. A taxonomic revision of the genus *Adela* Latreille (Lepidoptera, Adelidae) from Japan. *Transactions of Lepidopterological Society of Japan* 48:271–290.
Hirowatari T, Nagaike T. 1998. Biological notes on *Nemophora paradisea* (Butler, 1881) (Lepidoptera, Adelidae). *Transactions of Lepidopterological Society of Japan* 49:288–294.
Hirowatari T, Yamamoto H. 2004. Discovery of *Nemophora smaragdaspis* (Meyrick) (Adelidae) from Akiyoshidai, Japan. *Tinea* 18:30–35.
Hirowatari T, Kanazawa I, Liang XC. 2012. Four new species of the genus *Nemophora* Hoffmannsegg (Lepidoptera, Adelidae) from China. *Esakia* (52):99–106.
Hirowatari T, Yagi S, Ohshima I, et al. 2021. Review of the genus *Vespina* (Lepidoptera, Incurvariidae) with two new species from China and Japan. *Zootaxa* 4927 (2):209–233.
Hirowatari T, Yamanaka K. 1996. Biology of *Nemophora albiantennella* Issiki (Lepidoptera, Adelidae). 1. Host plants and daily activity pattern. *Jpn J Entomol* 64 (3): 619–626.
Hua LZ. 2005. *List of Chinese Insects*. Guangzhou: Sun Yat-sen University Press.
Huemer P, Mutanen M, Sefc KM, et al. 2014. Testing DNA Barcode Performance in 1000 Species of European Lepidoptera: Large Geographic Distances Have Small Genetic Impacts. *PLoS One* 9 (12):e115774.
Huemer P, Hebert PDN. 2015. *DNA-Barcoding der Schmetterlinge (Lepidoptera) Vorarlbergs (Österreich) - Erkenntnisse und Rückschlüsse*, 15. inatura – Forschung online, Nr. 36 S.
Huemer P, Hebert PDN. 2016. DNA barcode library for Lepidoptera from South Tyrol and Tyrol (Italy, Austria) – Impetus for integrative species discrimination in the 21st Century. *Gredleriana* 16 (X):141–164.
Katoh K, Standley DM. 2013. MAFFT Multiple Sequence Alignment Software Version 7: Improvements in Performance and Usability. *Molecular Biology and Evolution* 30 (4):772–780.

Kozlov MV. 1997. A taxonomic revision of the *divina* speices-group of the genus *Nemophora* Hoffmannsegg (Lepidoptera, Adelidae). *Deutsche Entomologische Zeitschrift* 44:137–145.

Kozlov MV. 2004. Annotated checklist of the European species of *Nemophora* (Adelidae). *Nota Lepidopterologica* 26:115–126.

Kozlov MV, Hirowatari T. 1997. A taxonomic revision of the *hoeneella* species-group of the genus *Nemophora* Hoffmannsegg (Lepidoptera, Adelidae). *Entomologica Scandinavica* 28:87–96.

Kumar S, Stecher G, Taamura K. 2016. MEGA7: molecular evolutionary genetics analysis version 7.0 for bigger datasets. *Molecular Biology and Evolution* 33 (7): 1870–1874. https://doi.org/10.1093/molbev/msw054.

Küppers PV. 1980. *Untersuchungen zur taxonomie und phylogenie der west-paläarktischen Adelinae (Lepidoptera: Adelidae)*. Karlsruhe: Verlag M. Wahl.

Kuroko H. 1961. The life history of *Nemophora raddei* Rebel (Lepidoptera, Adelidae). *Science Bulletin of the Faculty of Agriculture, Kyushu University* 18 (4):323–334.

Meyrick E. 1907. Descriptions of Indian Micro-Lepidoptera. *Journal of the Bombay Natural History Society* 17:976–994.

Meyrick E. 1912a. Adelidae, Micropterygidae, Gracilariadae. In: Wagner H, editor. *Lepidopterorum Catalogus*, 6; 1912. pp 1–68.

Meyrick E. 1912b. Lepidoptera Heterocera (Tineae). Fam. Adelidae. In: Wytsman P, editor. *Genera Insectorum. Fasc*, 133. Bruxelles: Verteneuil & L. Desmet. p 12. 1 pl.

Mori N. 1992. Observation of ovipositing behavior of *Nemophora rubrofasicia*. *Saga No Kontyu [Insects of Saga]* (26):403 (In Japanese).

Murata J, Shigenaga Y. 2018. *[Additional collecting locality of Nemophora smaragdaspis] Yamaguchi no Mushi [Insects of Yamaguchi]* (17). p 87 (In Japanese).

Mutanen M, Kivelä SM, Vos RA, et al. 2016. Species-level para-and polyphyly in DNA barcode gene trees: strong operational bias in European Lepidoptera. *Systematic Biology* 65 (6):1024–1040. https://doi.org/10.1093/sysbio/syw044.

Nielsen ES. 1985. A taxonomic review of the adelid genus *Nematopogon* Zeller (Lepidoptera: Incurvarioidea). *Entomologica Scandinavica (Suppl.)* 25:1–66.

Sasaki K, Yagi S, Hirowatari T. 2017. Biological notes on an upsurge of *Nemophora optima* in the vicinity of Fukuoka city, Japan. *Yadoriga* (254):2–10 (In Japanese).

Stamatakis A. 2014. RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* 30 (9):1312–1313. https://doi.org/10.1093/bioinformatics/btu033.

Wang HY, Park KT, Arita Y. 2000. Microlepidoptera. In: *Guide Book to Insects in Taiwan (20)*. Taipei: Shu Shin Books (In Chinese).