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Diversity of hawkmoths in Tashigang Forest Division, with new faunistic records for Bhutan

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Abstract

Hawkmoths are a charismatic, diverse group of moths that are well-studied worldwide. In this study, we explored and presented the first ever comprehensive hawkmoth checklist for Tashigang Forest Division, Bhutan with five new taxa records for the country. We conducted fauna exploration over a period of five years (2017–2021). Data were collected opportunistically from twelve different localities. Online database and the current literature on hawkmoths of Bhutan were referred to for correct species identifications and nomenclature. We recorded a total of 48 species belonging to 23 genera and four subfamilies. Macroglossinae Harris, 1839 was the most dominant subfamily with 29 species, followed by Smerinthinae Grote & Robinson, 1865 with 14 species, Sphinginae Latreille, [1802] with four and Langiinae Tutt, 1904 with one species. *Ampelophaga thomasi* Kitching and Cadiou, *Cechetra subangustata* Rothschild, *Macroglossum saga* Butler, *Rhagastis confusa* Rothschild and Jordan, and *Notonagemia analis* R. Felder are here reported as representing five new records to Bhutan. Further investigation in the area and in other parts of Bhutan appear necessary to discover more hawkmoth species and reveal endemism.

Key words: Langiinae, Macroglossinae, Smerinthinae, Sphinginae

Introduction

Recent estimates reported over 127,000 moth species globally (Chandra and Sambath, 2013; Sonne and Gaikwad, 2021), of which 12,000 (Sonne and Gaikwad, 2021) and 675 (Gielis and Wangdi, 2017) species were stated to occur on the Indian subcontinent and in Bhutan respectively. Hawkmoths are a charismatic and diverse group, represented by 205 genera and over 1,602 species described worldwide (Primo et al., 2013; Kitching et al., 2018). Hawkmoths belong to the order Lepidoptera Linnaeus, 1758, Superfamily Bombycoida Latreille, 1802, family Sphingidae Latreille, 1802 (Arandhara, 2016), and are also referred to as 'Sphinx moths'. Hawkmoth species diversity is highly concentrated in tropical and subtropical regions (Primo et al., 2013; Kitching et al., 2018). They play vital roles in ecosystems as pollinators for many plants and as prey for many predators, including bats and birds (Chettri et al., 2021).

Bhutan is a land-locked country with a total area of 38,394 km^2 (Thinley et al., 2021). The country is located within the Eastern Himalayan Biodiversity Hotspot (EH); the gathering point of two biogeographic realms, specifically, the Indo-Malayan and Palearctic realms.

With altitudes ranging from 65 m in tropical foothills to above 6,500 m in northern highlands, Bhutan is known for its rich biodiversity and insulated location surrounded by Nepal, India and China. The southern foothills are inhabited by typical Indo-Malayan species, whereas Palearctic species are known to occur at higher elevations.

In neighboring countries, hawkmoths are well studied, and a substantial amount of work has been conducted. In India, Athreya (2013) and Shah et al. (2018) reported the presence of 71 and 88 species in the states of Arunachal Pradesh and West Bengal respectively. Sambath (2011) reported the presence of 204 species in India, while Smith (2010) reported the presence of 129 species of hawkmoths in Nepal. However, in Bhutan, hawkmoths are relatively poorly known and have never been intensively investigated. A few published works include information on the hawkmoth fauna of Bhutan: Dudgeon (1898a, b), Dierl (1975), Irungbam and Kitching (2014), Geilis and Wangdi (2017), Jamtsho and Irungbam (2019), Irungbam and Norbu (2019), Nidup and Irungbam (2020), and Norbu et al. (2020), but the information remains fragmentary. In addition, the information on the diversity and distribution of hawkmoths of the Tashigang Forest Division (TFD) in eastern Bhutan is incomplete. Thus, to address this knowledge gap we present here the first baseline information on faunal diversity of hawkmoths of the Tashigang Forest Division.

In the present paper, we present the results of a survey conducted in Tashigang Forest Division over the past five years (2017–2021) and part of a further contribution to the inventory of Sphingidae moths of Bhutan.

Material and Methods

Study area

Tashigang Forest Division (TFD) is located between 27°22’ to 27°29’ N latitude and 91°22’ to 92°07’ E longitude, and it extends its jurisdiction over two eastern districts, Tashigang and Trashiyangtse (Fig. 1). Straddling the international border with Arunachal Pradesh, Indian state in the east, Tashigang Forest Division is a strategic corridor linking with a larger landscape of many other protected areas (PA) and Forest Divisions (FD) in eastern Bhutan (Norbu et al., 2022). The Tashigang Forest Division landscape experiences sub-tropical to temperate climate (Norbu et al., 2021), featured by hot to warm and wet summers, and cold and relatively dry winters, with an average annual temperature of 20.2 °C and precipitation of 1,000 to 2,000 mm (Norbu et al., 2019; Koirala et al., 2021). Three major rivers, Kholongchu, Drangmechu and Nyeramachu Rivers flow through the TFD landscape and make it an important water catchment. Covering an area of approximately 2,447.40 km^2, the elevation ranges from 470 m to above 4,400 m (Koirala et al., 2021). The area is dominated by forest cover (75%), which is composed of major forest types of fir forest, mixed conifer forest (MCF), pine forest, mixed pine-cool broadleaved forest, chirpine forest, cool broadleaved forest (CBF), warm broadleaved forest (WBF), alpine shrubs, alpine meadows, and a few plantations (Norbu et al., 2021).

The presence of mosaic environments of various altitude, geographical aspect, rich forest types, and human dominated landscape support ideal habitats for a wide array of flora and faunal elements including the apex predator Tiger *Panthera tigris* Linnaeus, 1758 (Thinley et al., 2020), Common leopard *Panthera pardus* Linnaeus, 1758, Dhole *Cuon alpinus* (Pallas, 1858) (Thinley et al., 2021), five morphs of Asiatic golden cat *Catopuma temminckii* (Vigors and Horsfield, 1827) (Norbu et al., 2022), Red panda *Ailurus fulgens* F. Cuvier, 1825, Musk deer *Moschus* sp. Linnaeus, 1758, Arunachal macaque *Macaca munzala* Sinha et al., 2005, 34 species of snakes (Koirala et al., 2021), 273 bird species (Norbu et al., 2021), *Podocarpus neriifolius* D.Don, a white poppy *Mecanopsis sinuate* Prain, critically endangered *Nardostacys jatammansi*s (D.Don) DC and many wildlife species.

Data collection

We conducted hawkmoth data collection from twelve localities of the Tashigang Forest Division (Table 1), the altitude of sites ranged from 800–2,900 m. The data collection was carried out mostly through opportunistic observation, employing no particular methodology. Unsystematic hawkmoth search was carried out frequently in pre-monsoon, monsoon, and post-monsoon seasons within the period of 2017–2021. Nocturnal field observation were made in and around walls and any structures of residential houses and institutions buildings under fluorescent bulbs, lamps, and tube lights kept lit throughout the night. In addition, hawkmoths observed during the day were noted wherever possible.

Opportunistic observations were also made during various field visits and by patrolling within the woodland and higher altitude areas. Individual specimens were not collected but were photographed using a digital camera (Cannon DC 18–135 mm lens) and available kits on site, and identified with standard references (Geilis and Wangdi, 2017; Irungbam and Irungbam, 2019). Further scrutiny was also achieved with the help of hawkmoth taxonomists for validation of the identifications. Historical records and reports were also reviewed. New additional records for Bhutan and their distributions were further assessed with available literature. Local experts of the country’s fauna were also consulted. The online repository and catalogue available for the Sphingidae of the Eastern Palearctic (Pittaway and Kitching, 2020), Moths of Asia (Nakao, 2020), and Sphingidae of Arunachal Pradesh, northeast India (Athreya, 2013) were also accessed to compare and confirm the identity of the specimen.

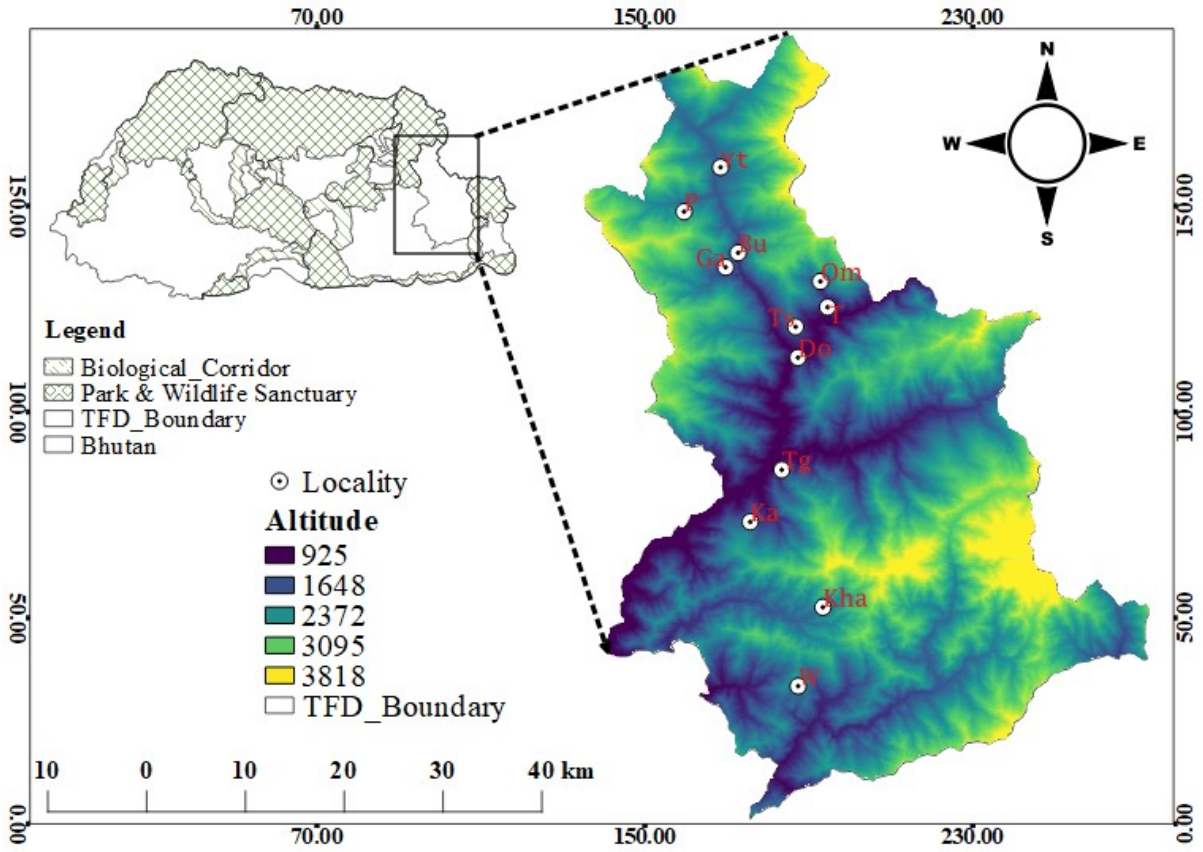

Figure 1: Map showing study location, Trashigang Forest Division, eastern Bhutan.

Table 1: Overview of data collection sites in the Trashigang Forest Division, eastern Bhutan.

Survey site	Coordinates	Elevation (m)	Habitat characteristic
Doksum	27.435°N 91.574°E	800	Settlement, river valley and chirpine forest
Tshenkharla	27.463° N 91. 572°E	1950	Settlement, hilltop and cool broadleaved forest
Omba	27.504°N 91.598°E	2700	Settlement and cool broadleaved forest
Toetsho	27.4805°N 91.6050°E	1400	Settlement, Warm broadleaved forest and chirpine forest with lemongrass
Buyang	27.531°N 91.514°E	1250	Cool broadleaved forest and river valley
Yangtse town	27.609°N 91.497°E	1800	Settlement, cool broadleaved forest and Bhutan white pine forest
Phordung	27.569°N 91.459°E	2200	Settlement and cool broadleaved forest
Gangkhar	27.518°N 91.501°E	2900	Settlement and cool broadleaved forest
Tashigang	27.333°N 91.556°E	1207	Settlement, chirpine forest with lemon grass
Kanglung	27.286°N 91.523°E	1814	Settlement and mixed forest
Khaling	27.2075°N 91.5963°E	2039	Settlement and cool broadleaved forest
Warmrong	27.136°N 91.570°E	2000	Settlement and cool broadleaved forest

The classification of each species cited in this article, such as its subfamily, scientific nomenclature, and common name, follows Kitching et al. (2018) and Kitching et al. (2014). For all identified species, general information on their distributions in Bhutan and flight time are provided (Table 2).

Table 2: List of hawkmoth species recorded in the Trashigang Forest Division, eastern Bhutan. **(*** new records to Bhutan); **District:** Bumthang (B), Chukha (C), Dagana (D), Gasa (G), Haa (H), Lhuntse (LT), Mongar (M), Paro (P), Pema Gyatshel (PG), Punakha (PU), Samdrup Jongkhar (SJ) Samtse (S), Sarpang (SP), Tashigang (TG), Thimphu (TP), Trashiyangtse (TY), Trongsa (TR), Tsirang (TS), Wangdu (W), Zhemgang (ZG); **Subfamily:** Macroglossinae, Smerinthinae, Langiinae, Sphinginae; **Locality:** Wamrong (W), Khaling (Kha), Kanglung (Ka), Tashigang (Tg), Doksum (Do), Toetsho, (T), Omba (Om), Tshenkharla (Ts), Buyang (Bu), Yangtse town (Yt), Phordung (P), Gangkhar (Ga).

Sl. No.	Subfamily	Scientific Name	Common Name	Locality	Flight Time	Distribution in Bhutan
1	Macroglossinae	*Acosmeryx naga* (Moore, [1858])	Common forest hawkmoth	Tg	June	TG, TS, ZG, SP, TR
2	Macroglossinae	*Acosmeryx omissa* Rothschild and Jordan, 1903	Obscure forest hawkmoth	Tg, Yt	August	TS, TG, SJ,TY
3	Macroglossinae	*Acosmeryx shervilli* Boisduval, 1875	Dull forest hawkmoth	Tg	September	TS, TG, SJ
4	Macroglossinae	*Elibia dolichoides* (R. Felder, [1874])	Green banded hawkmoth	Tg	September	TG, TS, ZG
5	Macroglossinae	*Ampelophaga khasiana* Rothschild, 1895	Scarce vine hawkmoth	Bu	June	TR, ZG, TY
6	Macroglossinae	*Ampelophaga rubiginosa* Bremer and Grey, 1853	Common vine hawkmoth	Bu, Tg	December, May	TS, TG, ZG,TY
7	Macroglossinae	*Ampelophaga thomasi* Kitching and Cadiou, 1998*	Thomas vine hawkmoth	Yt, Ga	July	TY
8	Macroglossinae	*Cechenea aegrota* (Butler, 1875)	Molted green hawkmoth	Tg	June	TG
9	Macroglossinae	*Cechetra lineosa* (Walker, 1856)	Striped green hawkmoth	Ga, P, Ts,Tg, W	May	TS, D, TG,TY
10	Macroglossinae	*Cechetra minor* (Butler, 1875)	Lesser green hawkmoth	Ts, K	August	TY
11	Macroglossinae	*Cechetra bryki* Ivshin and Krutov, 2018		Ga	July	TY
12	Macroglossinae	*Cechetra scotti* (Rothschild, 1920)	Scott's green hawkmoth	Ga, Ts, W	May	TS, TR, TG, TY
13	Macroglossinae	*Cechetra subangustata* (Rothschild, 1920)*	-	P	June	TY
14	Macroglossinae	*Eupanacra metallica* (Butler, 1875)	Metallic rippled hawkmoth	Yt, P, Ga	May	TS, D, TY
15	Macroglossinae	*Eupanacra perfecta* (Butler, 1875)	Model rippled hawkmoth	P	June	TY, TS
16	Macroglossinae	*Eupanacra sinuate* (Rothschild and Jordan, 1903)	Sinuous rippled hawkmoth	Ga	June	TY
17	Macroglossinae	*Hippotion celerio* (Linnaeus, 1758)	Silver-striped hawkmoth	Yt	July	TY, TS
18	Macroglossinae	*Macroglossum bombylans* Boisduval, 1875	Humble hummingbird hawkmoth	Do	July	TY, TS
19	Macroglossinae	*Macroglossum saga* Butler, 1878 *	Grey-tipped Humming bird hawkmoth	Do	October	TY
20	Macroglossinae	*Macroglossum pyrrhosticta* Butler, 1878	Burnt-spot humming bird hawkmoth	Kha	September	TG
21	Macroglossinae	*Neogurelca hyas* (Walker, 1856)	Even-banded hawkmoth	Do	August	TY
22	Macroglossinae	*Rhagastis confusa* Rothschild and Jordan, 1903*	Indistinct mottled hawkmoth	Ga, P	June	TY
23	Macroglossinae	*Rhagastis olivacea* (Moore, 1872)	Olive mottled hawkmoth	Ga	July	TY, TS
24	Macroglossinae	*Rhagastis velata* (Walker, 1866)	Veiled mottled hawkmoth	Tg	September	TS, SP, TG
25	Macroglossinae	*Theretra alecto* (Linnaeus, 1758)	Levant hunter hawkmoth	Yt, Tg	June	TS, SP, ZG, TG, TY
26	Macroglossinae	*Theretra lycetus* (Cramer, 1775)	White-egde hunter hawkmoth	Tg	July	TG

Table 2. (Continued)

Sl. No.	Subfamily	*Scientific Name*	Common Name	Locality	Flight Time	Distribution in Bhutan
27	Macroglossinae	*Theretra nessus* (Drury, 1773)	Yam hawk moth	Yt	September	TY
28	Macroglossinae	*Theretra sumatrensis* (Joicey and Kaye, 1917)	Southern spotted hunter hawkmoth	Do	September	TY
29	Macroglossinae	*Theretra tibetiana* Vaglia and Haxaire, 2010	Impatiens hawk moth	Tg	July	TG, TS
30	Smerinthinae	*Ambulyx ochracea* Butler, 1885	Ochreous gliding hawkmoth	Ga	July	TS, D, SP, C, SJ, TY
31	Smerinthinae	*Ambulyx sericeipennis* Butler, 1875	Common gliding hawk moth	Ga	June	TS, D, SP, TY
32	Smerinthinae	*Amplypterus mansoni* (Clark, 1924)	Manson's Mango hawkmoth	Ga,	May	TS, SP, TY
33	Smerinthinae	*Amplypterus panopus* (Cramer, 1779)	Mango hawkmoth	Bu, Ga, P, Tg, W	May	TS, D, SJ, TY
34	Smerinthinae	*Anambulyx elwesi* (Druce, 1882)	Pink & green hawkmoth	Yt, Tg	July	TG, TY
35	Smerinthinae	*Callambulyx poecilus* Rothschild, 1898	Lesser pink and green hawk moth	Ga	July	TS, TR, TY
36	Smerinthinae	*Clanidopsis exusta* (Butler, 1875)	White-streak hawkmoth	Tg	June	TG
37	Smerinthinae	*Marumba cristata* (Butler, 1875)	Common striped hawkmoth	Yt, Ga, Bu, Om	June	TS, D, SP, TY
38	Smerinthinae	*Marumba dyras* Walker, 1856	Dull swirled hawkmoth	Yt, Bu, Om, Ka, W, Tg	June	TS, SP, TR, TY, SJ
39	Smerinthinae	*Marumba spectabilis* Butler, 1875	Rosy swirled hawkmoth	Yt, Tg	July	TS, ZG, TY
40	Smerinthinae	*Marumba sperchius* (Menetries, 1857)	Large swirled hawkmoth	Yt, Bu, Ga	May-June	TS, SP, TY
41	Smerinthinae	*Polyptychus dentatus* (Cramer, 1777)	Stright-lined cranulate hawk moth	Bu, Tg	June	TG, TY
42	Smerinthinae	*Polyptychus trilineatus* Moore, 1888	Common crenulate hawkmoth	Bu, Ga, Tg	July	TS, TR, TG, TY
43	Smerinthinae	*Sataspes infernalis* (Westwood, 1847)	Brilliant carpenter-bee hawkmoth	Tg	September	TG, TY
44	Langiinae	*Langia zenzeroides* Moore, 1872	Apple hawk moth	Yt	May	TY
45	Sphinginae	*Acherontia lachesis* (Fabricius, 1798)	Greater death's head hawkmoth	Om, Ka	December	TS, D, C, H, ZG, SJ, TY
46	Sphinginae	*Agrius convolvuli* (Linnaeus, 1758)	Convolvulus hawkmoth	Do	June	TS, W, TR, C, TP, TY
47	Sphinginae	*Notonagemia analis* (R. Felder, 1874)*	Grey double-bristled hawk moth	Ga	July	TY
48	Sphinginae	*Psilogramma increta* (Walker, 1865)	Plain grey hawk moth	Ts, T, Tg	May, September	TY

Results

A total of 48 species (i.e. 48.98% of species known from Bhutan (N= 98 according to Norbu et al. (2020)) belonging to 23 genera and four subfamilies were recorded from the Tashigang Forest Division (Table 3, Figs. 2–3). Of these, five species: *Ampelophaga thomasi* Kitching and Cadiou, 1998; *Cechetra subangustata* Rothschild, 1920; *Macroglossum saga* Butler, 1878; *Rhagastis confusa* Rothschild and Jordan, 1903; and *Notonagemia analis* C. Felder and R. Felder, 1874 (Kitching et al., 2014) are new records (Figs. 4e, 4j, 4p, 4s, 7d and Table 2) for the hawkmoth fauna of Bhutan. The number of species also differs among the four subfamilies (Fig. 3). The most diverse subfamily is Macroglossinae (n= 29, 60% of collected species), followed by Smerinthinae (n= 14, 29%; Fig. 5), Sphinginae (n= 4, 8%; Fig. 7), and Langiinae (n= 1, 2%; Fig. 6). A checklist of all 48 observed hawkmoths species is provided Table 2 with details about the sites where these species were spotted and about their known distribution in Bhutan.

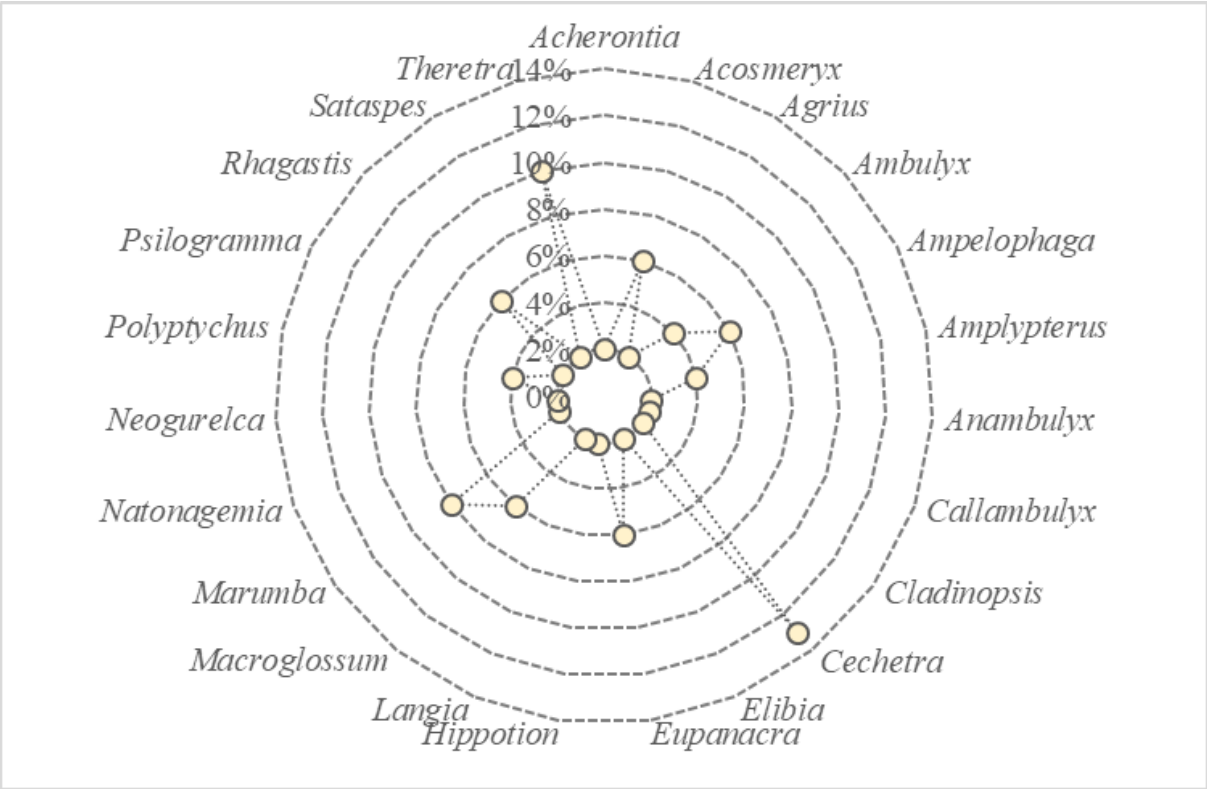

Figure 2: Distribution of generic diversity of hawkmoth species recorded in the Trashigang Forest Division, eastern Bhutan.

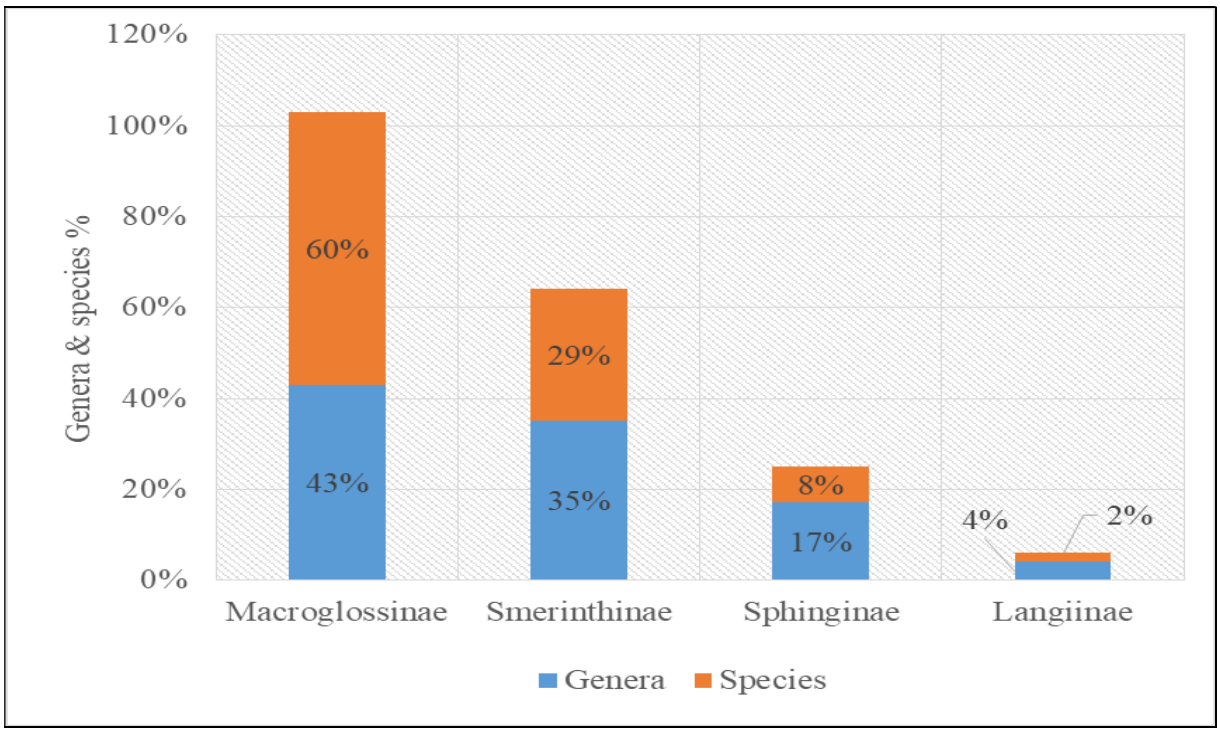

Figure 3: Distribution of hawkmoth genera and species diversity within the four sub-families recorded in the Trashigang Forest Division, eastern Bhutan.

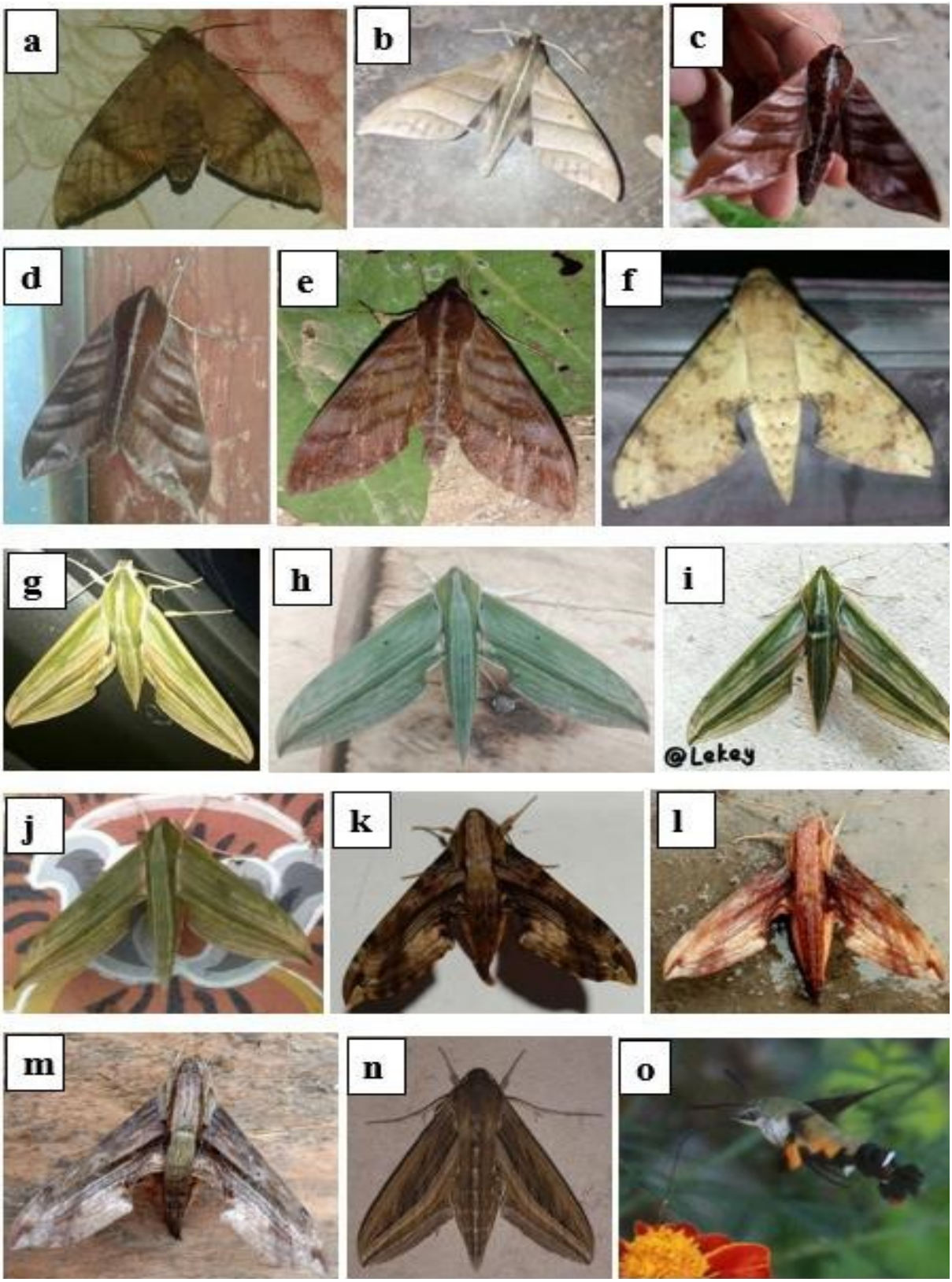

Figure 4: Adults of subfamily Macroglossinae recorded in the Trashigang Forest Division, eastern Bhutan: **a**, *Acosmeryx shervilli*; **b**, *Elibia dolichoides*, **c**, *Ampelophaga khasiana*; **d**, *Ampelophaga rubiginosa*; **e**, *Ampelophaga thomasi**; **f**, *Cechenea aegrota*; **g**, *Cechenena lineosa*; **h**, *Cechetra bryki*; **i**, *Cechetra scotti*; **j**, *Cechetra subangustata**; **k**, *Eupanacra metallica*; **l**, *Eupanacra perfecta*; **m**, *Eupanacra sinuata*; **n**, *Hippotion celerio*; **o**, *Macroglossum bombylans*; **p**, *Macroglossum saga**; **q**, *Macroglossum pyrrhosticta*; **r**, *Neogurelca hyas*; **s**, *Rhagastis confusa**; **t**, *Rhagastis olivacea*; **u**, *Rhagastis velata*; **v**, *Theretra lycetus*; **w**, *Theretra nessus*; **x**, *Theretra sumatrensis*, **y**, *Theretra tibetiana*; **y1**, *Acosmeryx naga.* *= new record for Bhutan.

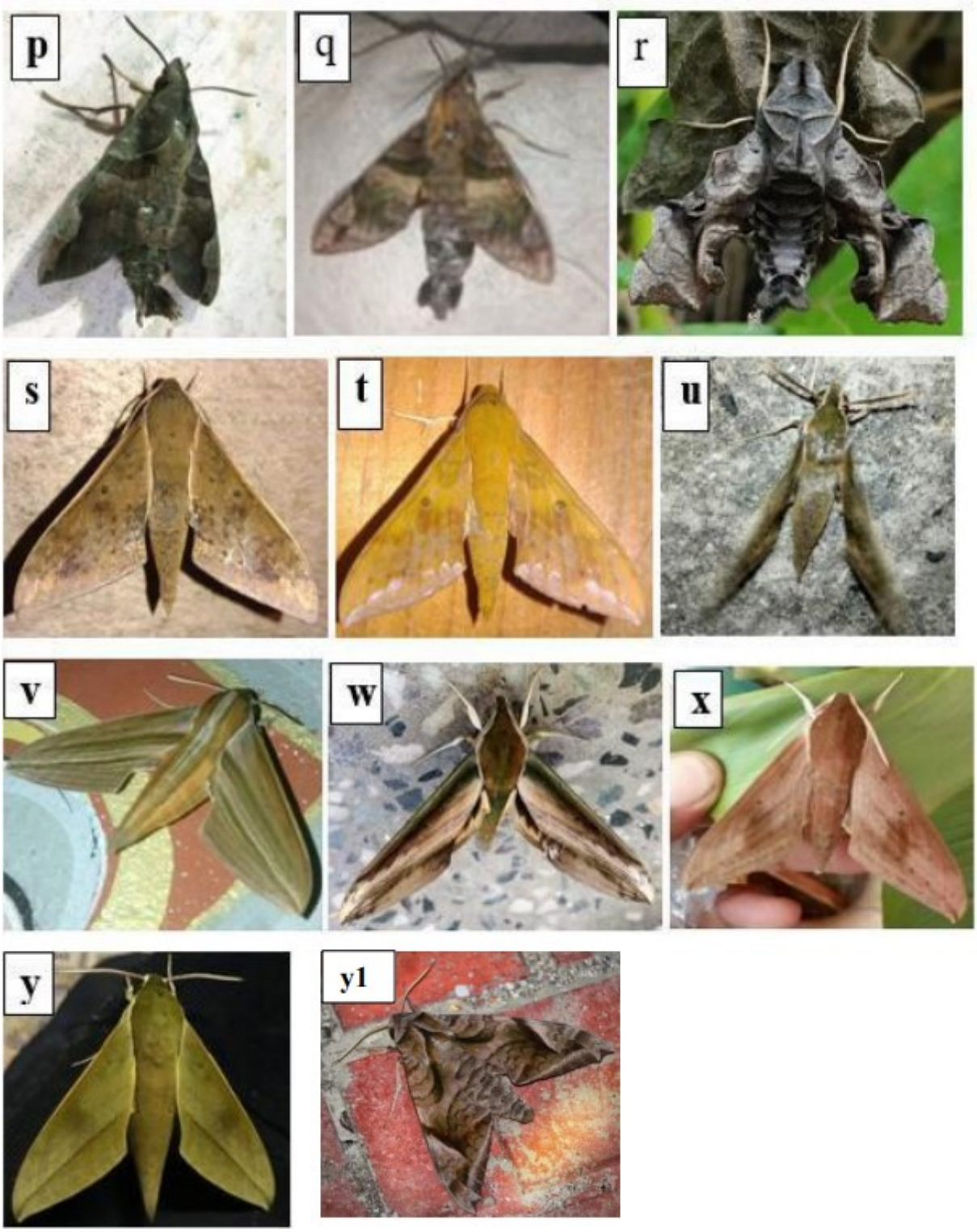

Figure 4. (Continued)

Discussion

The present survey (2017–2021) of twelve localities restricted to the Tashigang Forest Division (eastern Bhutan), unveiled a high diversity of hawkmoths. The earlier studies of Dudgeon (1898a, b) reported on moths of just the lower elevations of the Bhutan Himalaya, while Dierl (1975) listed 10 hawkmoths species from eastern Bhutan. Thus, a vast area of eastern Bhutan, which is known to be very rich in butterfly species (Wangdi et al., 2012; Irungbam and Irungbam, 2019) remains unstudied. In recent times, Irungbam and Kitching (2014) inventoried 27 species from the Tsirang district of southern Bhutan. Geilis and Wangdi (2017), who conducted surveys in many parts of Bhutan, produced an updated list of 63 species. Irungbam and

Irungbam (2019) reported 93 species in their recent review paper which is the most comprehensive checklist of hawkmoths in the country. Later, the confirmed hawkmoths species in Bhutan was raised to 98 species with the most recent new records of *Theretra sumatrensis* Joicey and Kaye, 1917 (Kitching et al., 2014) from the Trashiyangtse district of eastern Bhutan (Norbu et al., 2020).

As the present work is the first comprehensive study of hawkmoths focusing on overall diversity in the Tashigang Forest Division, the key outcome of this work is its report of 48 species among which five species are cited for the first time in the country. This brings the number of species of hawkmoths recorded in Bhutan to 103. Among these, members of the subfamily Macroglossinae were predominant. The present study has been carried out to investigate a previously undocumented family of moths, and it represents a small step towards a complete understanding of the taxonomic diversity of hawkmoths species in eastern Bhutan.

Aside from providing a preliminary checklist, our findings also suggest that the areas with heterogeneous mosaic landscapes of varying topography, elevation, weather, climate, and rich vegetation pattern offer a diversity of potential habitats favoring the diversity of insects. Surveys in other regions of Bhutan are therefore anticipated to add more species, and a systematic exploration in all parts of the country is recommended to better understand the diversity of hawkmoths in Bhutan and reveal patterns of endemism.

Table 3: Genera based species relative abundance (Ra) of hawkmoths recorded in Trashigang Forest Division, eastern Bhutan.

Sl. No.	Genera	Number of species	Relative abundance (Ra)
1	*Acherontia*	1	0.02
2	*Acosmeryx*	3	0.06
3	*Agrius*	1	0.02
4	*Ambulyx*	2	0.04
5	*Ampelophaga*	3	0.06
6	*Amplypterus*	2	0.04
7	*Anambulyx*	1	0.02
8	*Callambulyx*	1	0.02
9	*Cladinopsis*	1	0.02
10	*Cechetra*	6	0.13
11	*Elibia*	1	0.02
12	*Eupanacra*	3	0.06
13	*Hippotion*	1	0.02
14	*Langia*	1	0.02
15	*Macroglossum*	3	0.06
16	*Marumba*	4	0.09
17	*Natonagemia*	1	0.02
18	*Neogurelca*	1	0.02
19	*Polyptychus*	2	0.04
20	*Psilogramma*	1	0.02
21	*Rhagastis*	3	0.06
22	*Sataspes*	1	0.02
23	*Theretra*	5	0.10
	Total species	**48**	**1.00**

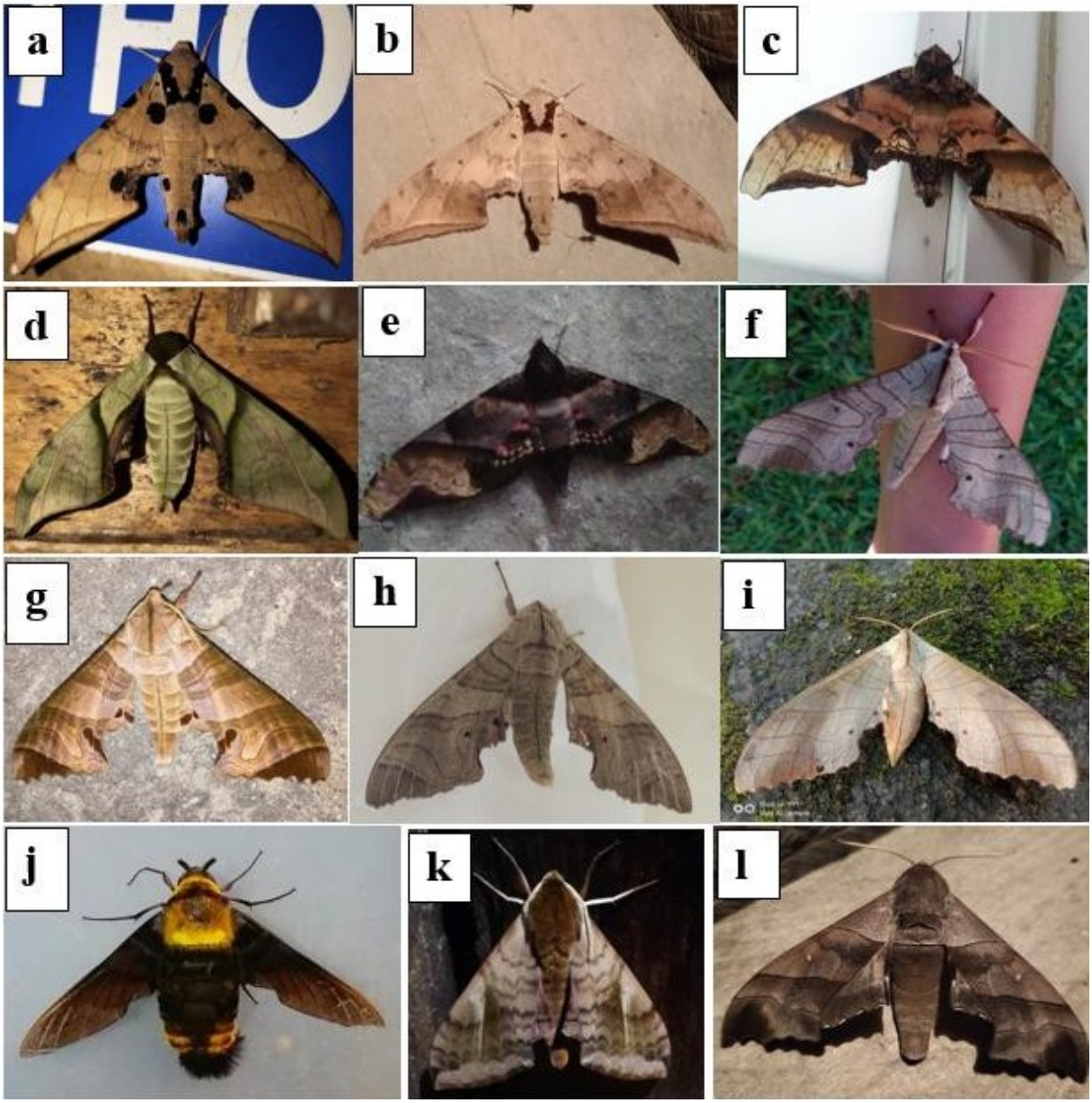

Figure 5: Adults of subfamily Smerinthinae recorded in the Trashigang Forest Division, eastern Bhutan: **a**, *Ambulyx ochracea*; **b**, *Ambulyx sericeipennis*; **c**, *Amplypterus mansoni*; **d**, *Callambulyx poecilus*; **e**, *Amplyterus panopus*; **f**, *Marumba sperchius*; **g**, *Marumba spectabilis*; **h**, *Marumba dyras*; **i**, *Marumba cristata*; **j**, *Sataspes infernalis*; **K**, *Cladinopsis exusta*; **l**, *Polyptychus trilineatus*.

Figure 6: An adult of subfamily Langiinae in the Trashigang Forest Division, eastern Bhutan: **a**, *Langia zenzeroides*.

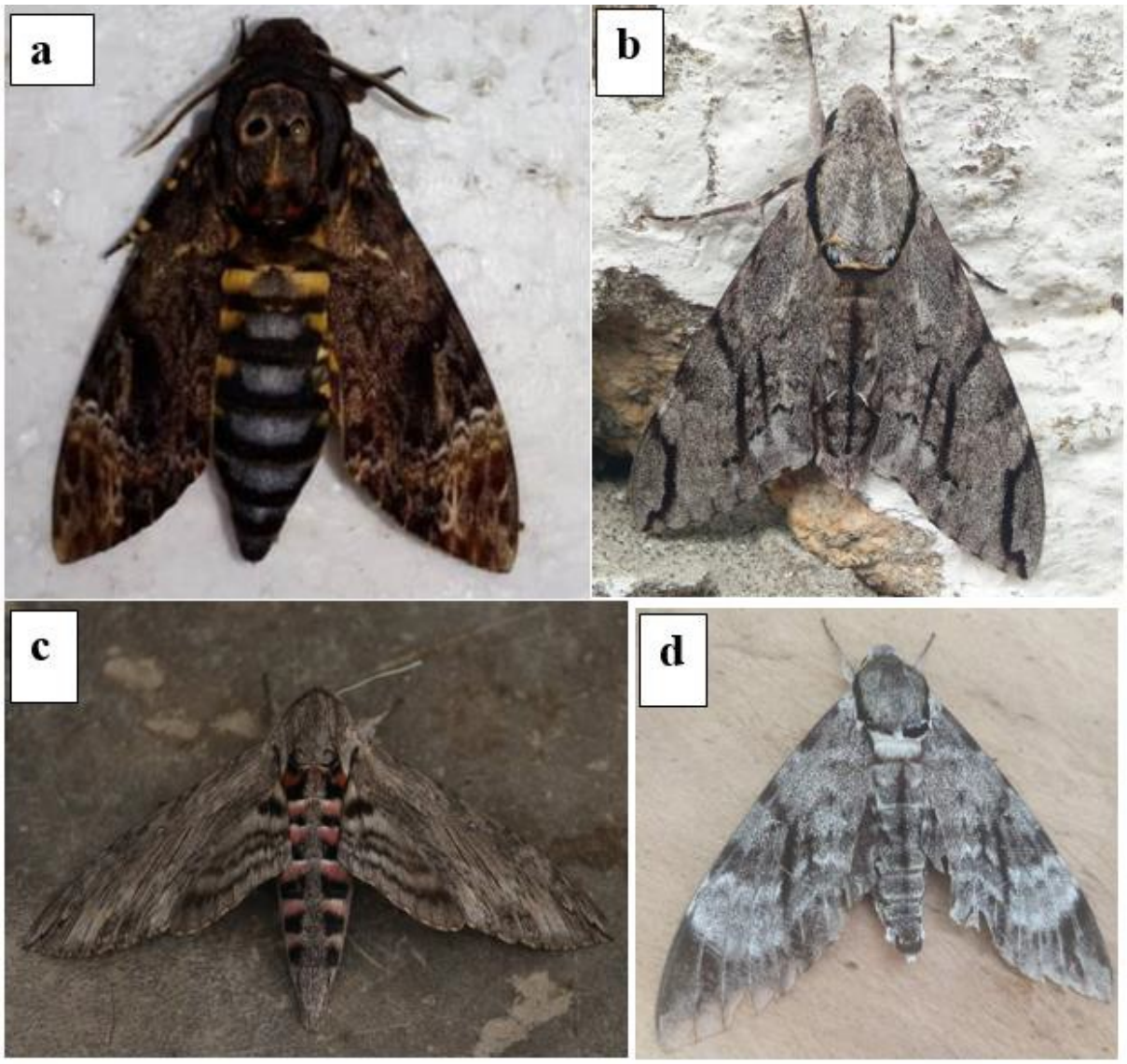

Figure 7: Adults of subfamily Sphinginae recorded in the Trashigang Forest Division, eastern Bhutan: **a**, *Acherontia lachesis*; **b**, *Psilogramma increta*; **c**, *Agrius convolvuli*; **d**, *Notonagemia analis**. *= new record for Bhutan.

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Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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