Taxonomy of *Rhodostrophia jacularia* (Hübner, 1813) – a Sterrhinae moth with variable female wing shape (Lepidoptera: Geometridae)

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Abstract. The phenomenon of gradual transformation of the wing shape and size in the Palaearctic sterrhine moth *Rhodostrophia jacularia* (Hübner, 1813) is described (Geometridae). The females of this species have shorter wings than the males throughout the species' distribution area, but they are capable of flying, apart from a mountain population in the Russian Altai near the Chinese and Mongolian border. These earthbound females run and jump on the ground and their facies is characterized by concave wing margins and smaller wing surfaces, unlike other specimens studied. The taxonomy of *R. jacularia* is revised, and a neotype is designated for *R. jacularia* because the original syntype(s) has been lost. *R. jacularia* ssp. *minor* Alphéraky, 1892 **syn. n.** and *R. tyugui* Vasilenko, 1998 **syn. n.** are downgraded to the synonymy of *R. jacularia*. *R. jacularia* is redescribed, the adults and genitalia are illustrated and a distribution map of the species is given.

Key words. Lepidoptera, Sterrhinae, *Rhodostrophia*, narrow-winged, female, new synonyms, taxonomy.

Introduction

Modification of the wing shape has taken a variety of forms. Within Geometridae a well-documented and widespread example of this is brachyptery, or reduction of wing length. This feature is restricted to the females only and it is considered a derived state that has evolved independently many times, and it has been reported to occur at least in the subfamilies Alsophilinae, Larentiinae and Ennominae (Pellmyr 1980; Hausmann 2001; Sattler 1991). Brachyptery is most widespread among species that live as adults under cold conditions, i.e. they appear in early spring or late autumn.

So far, there has been no record of brachyptery in Sterrhinae, although other wing modifications, namely sexual dimorphism, is widespread in the subfamily, and in many instances the females have shorter wings compared to males. To mention a few examples, this is well seen in the European Sterrhini species *Limeria macraria* Staudinger, 1892 and *Idaea attenuaria* (Rambur, 1833) (Hausmann 2004). The reduction of wing length is pronounced in *Scopula (Stigma) kuldschaensis* (Alphéraky, 1883) (Scopulini) also, whose female is not only smaller than the male but it is also very reluctant to fly at all (Prout 1912–16; Sihvonen 2005). Other wing shape modifications of Sterrhinae have not been reported. In the summer of 2000 a Finnish lepidopterological expedition was made to the Altai Mountains, Russia, where a large number of *Rhodostrophia jacularia* (Hübner, 1813) specimens were collected from a high altitude locality. The females of this population differed from other known populations by having narrow wings with concave margins, and the specimens did not fly at all. Instead, if disturbed, the specimens ran and jumped on the ground like spiders.

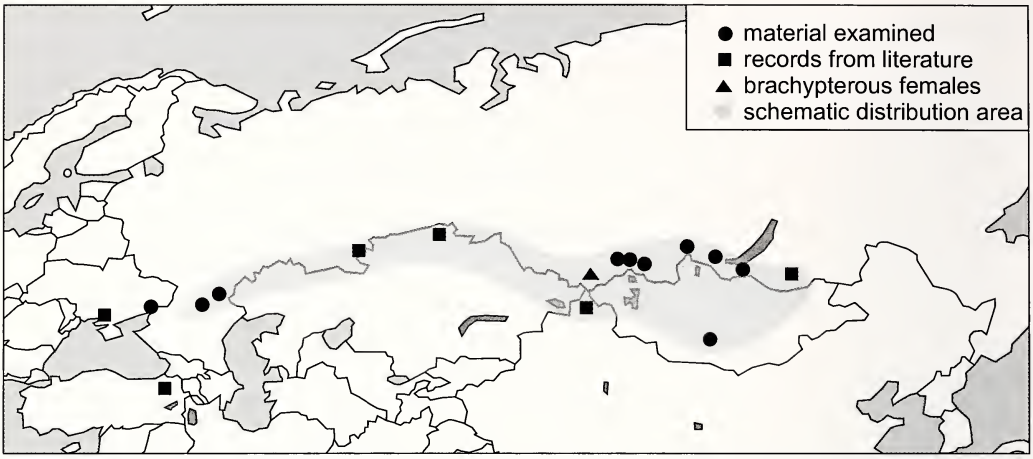


Fig. 1. Distribution area of *Rhodostrophia jacularia*. Literature records (black square): Vojnits 1976; Kostjuk et al. 1994; Riemis 1994; Viidalepp 1996; Hausmann 2004.

Fig. 2. Habitat of *Rhodostrophia jacularia* in Altai mountains, Russia (Kuraisky range, 2500 m), where narrow-winged females were found. Locality is dominated by *Artemisia* spp. (Asteraceae). Photo: Kari Nupponen, 26.vi.2000.

The description of *Rhodostrophia jacularia* is based on a specimen(s) whose type locality is given imprecisely as 'Europe'. The type specimen(s) has been lost but they probably originate from the lower Volga Region, Russia, because all the known old records of this species, i.e. those from the 18th century, are from that area. A closely related species to *R. jacularia* has been described from the Altai Mountains, Russia, namely *R. tyugui* Vasilenko, 1998. The description is based on males only, and the species was diagnosed to be separated from *R. jacularia* using structures of the male genitalia only: (roughly translatated from Russian): 'the valva of new species [*tyugui*] resembles that of *jacularia*, but it is considerably larger and has more massive sacculus, and by the structure of costa. In *tyugui* the margin of costa is round (in *jacularia* it is

right-angled)'. Hausmann (2004) diagnosed the *jacularia* species-group and considered it to have three species: *jacularia* (Hübner), *tyugui* Vasilenko, 1998 and *solitaria* (Christoph, 1887). The species group is characterised by dark and undulated fasciae of the forewings, male hindtibia that has four spurs, valva of the male genitalia that is flat and phallus that has a single cornutus. Further, the female genitalia has short and stout apophyses anteriores and papillae anales are usually spinose.

Thus far, both sexes of *R. jacularia* are reported to be fully-winged although females tend to be slightly smaller. The wingspan of the males is between 25–28 mm, whereas those of the females is between 23–25 mm (Hausmann 2004). Both sexes are attracted to light and the females are capable of flying although the female ratio at light is very low, between 5–10%.

In this paper we review the taxonomy of *R. jacularia* and show that the above-mentioned diagnostic characters of *R. tyugui* are suspect. We also present material from the Altai Mountains, Russia, where a population of *R. jacularia* was found, whose females have markedly narrower wings, quite different in shape to other known specimens. These females are not capable of flight unlike specimens from other populations.

Material and conventions

Specimens have been studied from the following collections (acronyms after Evenhuis & Samuelson 2005):

coll. Nupponen	Private collection of Kari Nupponen, Espoo, Finland
FMNH	Finnish Museum of Natural History, Helsinki, Finland
SZMN	Siberian Zoological Museum,Institute of Animal Systematics and Ecology, Novosibirsk,Russia
ZIN	Zoological Institute, Russian Academy of Sciences, St Petersburg, Russia

Further, a large population sample from the Altai Mountains, Russia (coll. Nupponen), was studied, where *R. jacularia* occurs sympatrically with *R. tyugui*.

Specimen data are provided as they appear on the labels. Information from each type specimen is enclosed within single quotation marks, a vertical line with a space on each side separates lines of the label, a semicolon separates the labels, information enclosed by angled brackets includes comments and square brackets provides further details about the specimen or label.

Rhodostrophia jacularia (Hübner, 1813) Figs. 1–15

Geometra jacularia Hübner, 1813: pl. 84 fig. 431. Type locality: Europe (probably lower Volga region).

Eusarca jacularia var. *minor* Alphéraky, 1892: 71. Type locality: Western China: Ordosse, Tai-tou-ahi, near River Oulane-Morine. **syn. n.** Scoble 1999 (*Rhodostrophia acularia* ssp. *minor*).

Rhodostrophia tyugui Vasilenko, 1998: 1138, figs. 2, 4. Type locality: Russia, Altai, South Chyua Range. **syn. n.**

Figs. 3–5. Type specimens of examined material. **3.** *Rhodostrophia jacularia* (Hübner, 1813). Neotype from Sarepta, Russia (FMNH). **4.** *Rhodostrophia jacularia* var. *minor* (Alphéraky, 1892). Lectotype from western China, Ordosse (ZIN) (photo: Fritz, Erlacher & Hausmann, Zoologische Staatssammlung München). **5.** *Rhodostrophia tyugui*, Vasilenko, 1998. Holotype from Altai mountains, Russia (SZMN) (photo: Vasilenko, Siberian Zoological Museum, Novosibirsk).

Material. *Geometra jacularia* Hübner, 1813. Syntype(s) lost. – *Rhodostrophia jacularia* (Hübner, 1813). Neotype ♂ (Fig. 3) (hereby designated; external appearance of the selected neotype agrees with the specimen that is illustrated in the original description of this species by Hübner). Labelled: 'NEOTYPE | Rhodostrophia ♂ | jacularia (Hübner, 1813) [red rectangle label]; 22.6 [18]94 | S[a]r[e]pta' (FMNH). – *Eusarca jacularia* var. *minor* Alphéraky, 1892. Lectotype ♂ (Fig. 4) (designated by Hausmann 2004). Labelled: 'Lectotypus: ♂ | Rhodostrophia | jacularia minor | Alphéraky | design.: [red rectangle label]; v. minor | Alph | ♂[green rectangle label]; VIII 1884 | Ordos <western China, Ordosse, Tai-tou-hai, near River Oulane-morine> | Potanine [green rectangle label]; 85; Zool. Inst. | Acad. Sci. USSR | Leningrad' (ZIN). – *Rhodostrophia tyugui* Vasilenko, 1998. Holotype ♂ (Fig. 5) Labelled: 'HOLOTYPUS | Rhodostrophia tyugui | sp. nov. | S.V. Vasilenko det. [red rectangle label]; RUSSIA, Altai Republic | South Chuya Range | river Kokuzek headwater, locality Kyp, 2500 m | 30.VI. 1982 (Yu. E. Perunov leg) [in Russian]' (SZMN).

Rhodostrophia jacularia. 485♂ (12 genitalia), 30♀ (7 genitalia). **Russia**. Tuva republic, several locations: 71♂ (1 genitalia) Irbitei [50°44'N 93°08'E, 1000 m]; 1♂ Erzin [50°16'N 94°54'E, 1250 m]; 8♂ Khol-oozha [50°45'N 94°29'E, 1250 m]; 10♂, 2♀ (2 genitalia) Ust-Ujuk [52°04'N 94°22'E, 670 m]; 26♂ Kyzyl [51°43'N 94°27'E, 700 m]; 3♂ Tannu-Ola mts. [50°45–50'N 92°29–94°19'E, 1250–2000 m]; 8♂ (1 genitalia), 2♀ (1 genitalia) Sarepta, 15.vi.[18]94, coll. Duske; 2♂ Irkut, coll. Duske; 2♂ Munko Sardyk, Sajan mt.; 1♂ Saratow, coll. Winter; 1♂ Ross., mer., Staudinger (all in FMNH). 2♂, 2♀ Volgograd district, Volgograd 80 km NW, near Ilovla village, sandy steppe, 02.vi.2001; 2♂, 2♀ Volgograd oblast, Frolovo village 20 km SW, sandy steppe, 16.–17.v.2005; 330♂ (6 genitalia), 20♀ (3 genitalia) Altai mountains, Kuraisky hrebet, 50°16'N 87°50–55'E, 1500–2500 m, 25.vi.–4.vii.2000; 9♂ (2 genitalia), 2♀ (1 genitalia) Altai mnts, Kuraiskaja steppe, 50°16–20'N 87°50–55'E, 1500–2800 m, 05.–11.vii.2001; 6♂ (2 genitalia) S-Buryatia, Hamar Daban mnts, Murtoy river, village 6 km NW of Gusinoe ozero, forest steppe, 51°11–13'N 106°10–12'E, 700 m, 19.vi.2002; 2♂ S-Buryatia, lake Gusinoe ozero, steppe, 51°09'N 106°16'E, 550 m, 18.vi.2002 (all leg. et coll. T. & K. Nupponen). 1♂ **Mongolia**, Omnogov, Aimak, Bayandalai, Somon, Zoolon uul, 1700 m, 43°21'N 103°11'E, 27–30.5.1997, Yu. Marusik (FMNH).

Rhodostrophia tyugui. 6♂ (3 genitalia) **Russia**, Altai mountains, Kuraisky hrebet, 50°16'N 87°50–55'E, 1500–2500 m, 28.vi.–3.vii.2000, T. & K. Nupponen leg. (coll. Nupponen).

Redescription. Measurements. Forewing length ♂ 14–18 mm, ♀ 12–14 mm.

Head. Labial palpi with erect, flat scales, light brown. Proboscis long. Front dark brown; interantennal ridge, scape, collar, antennae above light brown. Male antennae bipectinate, female antennae filiform.

Thorax. Thorax and legs beige except fore- and midleg femur and tibia dark brown cephally; male and female hind tibia with 2 + 2 spurs. Forewing colour variable, from light brown to dark brown to red brown; transverse lines wide, brown; transverse anterior line slightly concave, inner margin bordered with white; transverse posterior line wider, undulate, outer margin bordered with white; terminal line weakly developed,

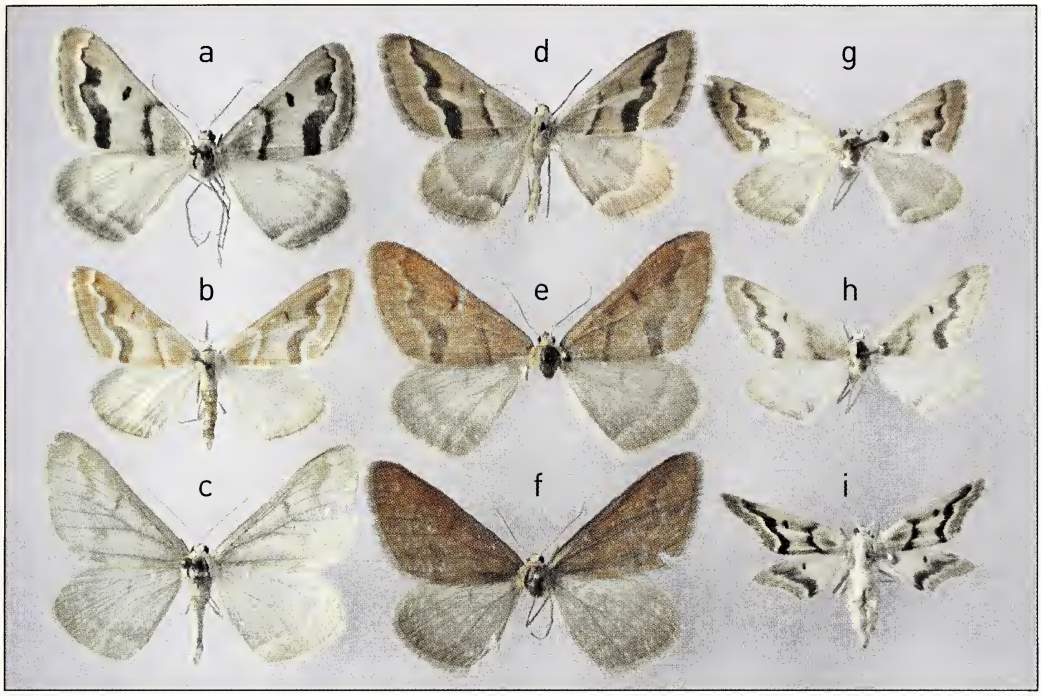
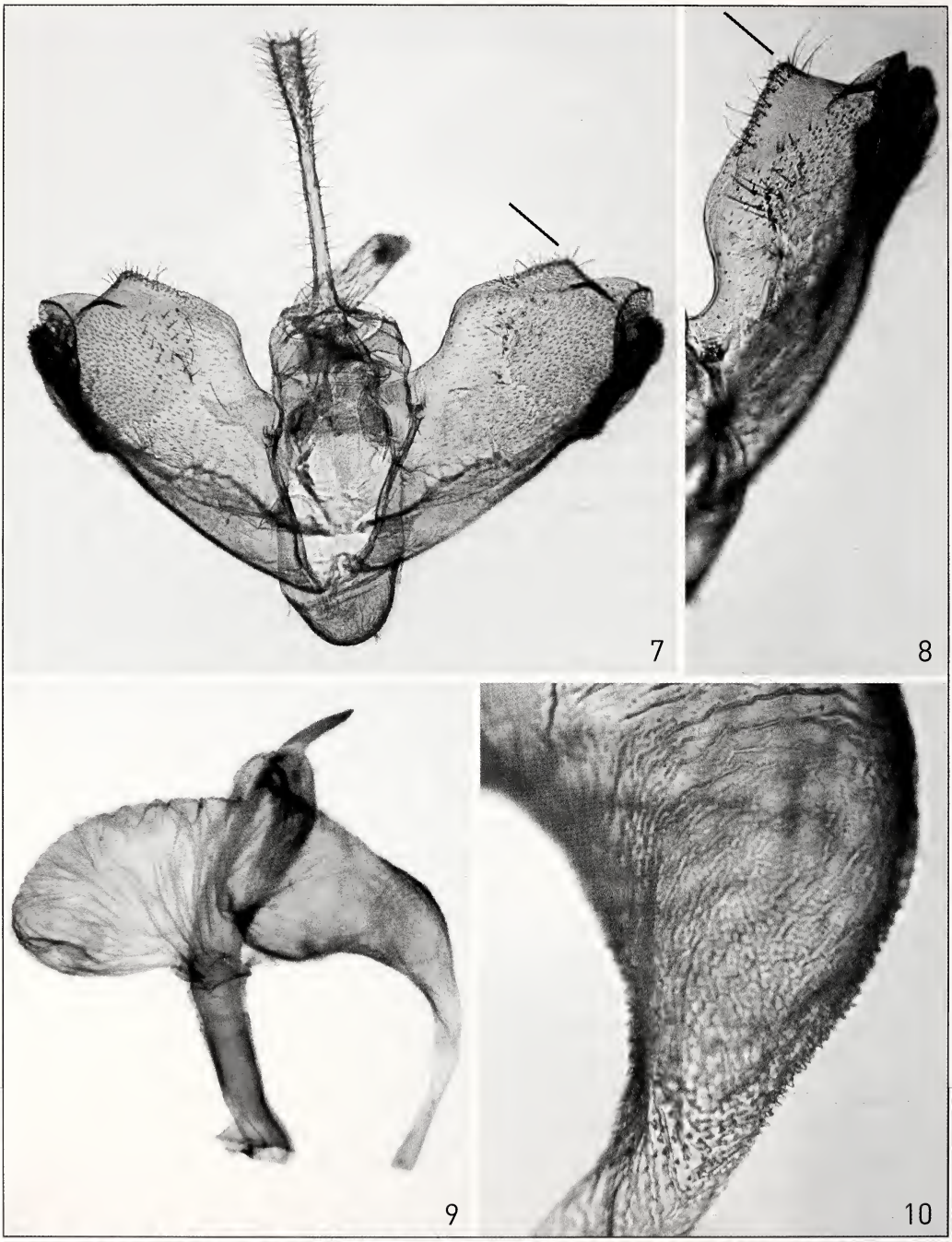


Fig. 6. Variation of external appearance of *Rhodostrophia jacularia*. **a.** ♂, Russia, Altai mountains (coll. Nupponen), **b.** ♂, Russia, Tuva, Tannu-Ola mountains (FMNH), **c.** ♂, Russia, Altai mountains (coll. Nupponen), **d.** ♂, Russia, Irkutsk (FMNH), **e.** ♂, Russia, Altai mountains (coll. Nupponen), **f.** ♂, Russia, Altai mountains (coll. Nupponen), **g.** ♀, Russia, Sarepta (FMNH), **h.** ♀, Russia, Tuva, Ust-Ujuk (FMNH), **i.** ♀, Russia Altai mountains (coll. Nupponen).

dark brown, complete; fringes concolorous with wings; discal spots distinct, round, brown. Hindwings paler; only transverse posterior line visible, outer margin bordered with white; wing margins of narrow-winged, brachypterous females concave. Wings below without markings.

Abdomen. Abdomen coloured as thorax and wings, light brown. Tympanal organs large, also in female; ansa narrow at base, widens above it, tip hammer-headed; medial pouch between cavi tympani absent. Sternites 3–7 and tergites 1–7 of male weakly sclerotized, undifferentiated; anterior margin of male 8th sternite with round, weakly sclerotized area, posterior margin with two round lobes, medially invaginated; male 8th tergite with narrow medial ridge (Fig. 11). Female sclerites undifferentiated.

Male genitalia (Figs. 7–10). Uncus long, narrow, slightly bifid at tip, setose apically. Tegumen weakly sclerotised. Gnathos fused, bare. Valva broad, concave, dorsal margin markedly bent, angle at costa margin appears different if viewed from different angles (Figs. 7, 8); ventro-terminal margin strongly spinose. Juxta plate-shaped. Transtilla fused, sclerotised, straight, wide plate. Vinculum small, margin evenly round. Phallus (Fig. 9) round, bent ventrally, apex with strong, cornutus-like projection; caecum small, round ending. Vesica (Fig. 9) without cornutus, large, opens ventrally, with three large diverticula, one dorsal and two lateral; dorsal and left lateral



Figs. 7–10. Male genitalia of *Rhodostrophia jacularia*. **7.** PS1015, valvae spread open but not pressed flat as in Fig. 15. **8.** PS1015, right valva, valva not spread open. **9.** PS1015, phallus in lateral view. **10.** PS1015, base of ductus ejaculatorius.
Shape of sacculus margin was used as a diagnostic feature by Vasilenko (1998) to separate *R. jacularia* and *R. tyugui*. Appearance of the costa margin depends on the angle from which the valva is examined (indicated in Figs. 7, 8).

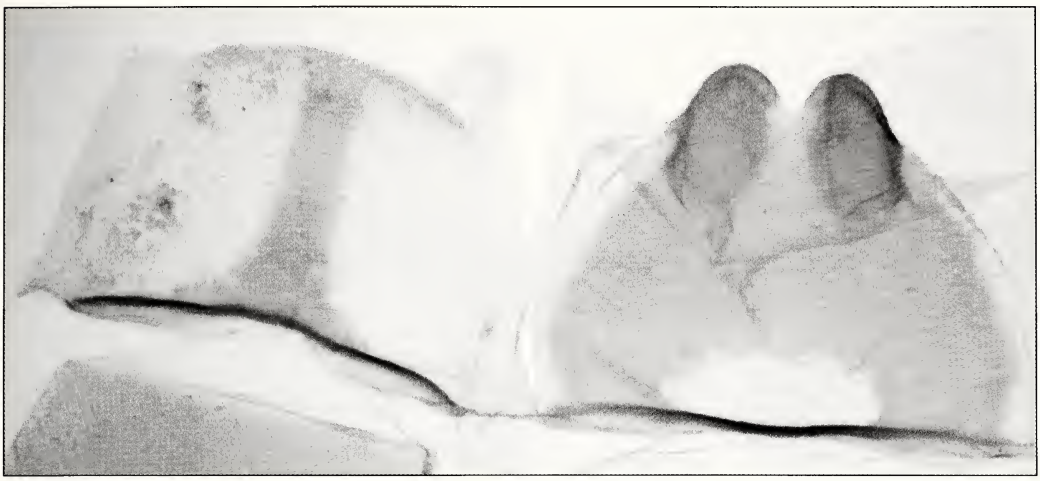
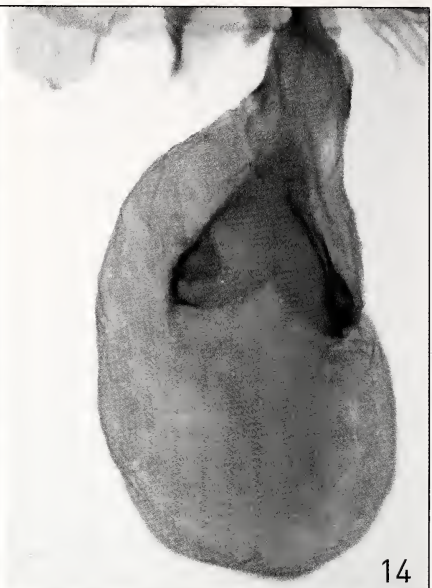


Fig. 11. *Rhodostrophia jacularia* ♂, PS965, 8th abdominal segment.

diverticula (when viewed dorsally) round, invaginated; right lateral diverticulum straight, tube-form, turns ventrally at distal end; ductus ejaculatorius opens from distal end of right lateral diverticulum, heavily serrated at base (Fig. 10).

Female genitalia (Fig. 12). Papillae anales rounded, fused, surface smooth; several laterally pointed spines caudally. Apophyses posteriores stout, straight, long; apophyses anteriores about 1/3 length of apophyses posteriores. Lamella postvaginalis absent; lamella antevaginalis a small, round plate; large membraneous invaginations laterally on 7th sternite. Ostium bursae in distal margin of 7th sternite, ventral margin sclerotised, round; ductus bursae sclerotised, round; ductus seminalis wide at base, opens from junction of ductus bursae and corpus bursae; corpus bursae round, elongated, two membraneous invaginated sacs dorsolaterally; signum horseshoe-shaped (Figs. 13–14).

Variation (Fig. 6). Sexually dimorphic species; females smaller, wings narrower and outer margin convex or concave. The thickness and colour of the transverse lines and the shape of the discal spots varies on the wings. The ground colour varies continuously from light brown (e.g. Sarepta) to dark brown (e.g. Altai, Irkutsk) to red-brown (Altai). The discal spot shape varies from lunular (e.g. Sarepta) to ovoid (Altai, Mongolia). Males from Altai are the largest and the forewing shape is rounded. A number of specimens from South Buryatia and Sarepta have a distinct white wedge-shaped area in forewing. The amount of intrapopulation variation in the external appearance of males in the Altai Mountains (Kuraisky range) (n=336) is large (Figs. 6a, c, e, f). Light brown is the dominant ground colour (n=325), transitional light brown-red brown (n=5) and red-brown (n=6) are considerably fewer. Females from Sarepta have a triangular wing shape and the wing margin is convex (Fig. 6g) whereas females from Altai have narrow, elongated wings and the wing margin is concave (Fig. 6i). There is little variation in the male and female genitalia.



Figs. 12–14. Female genitalia of *Rhodostrophia jacularia*. **12.** PS848, ventral view. **13.** PS848, corpus bursae in dorsolateral view showing membraneous invaginated sacs (transmitted light image). **14.** PS1016, corpus bursae in dorsal view showing horseshoe-shaped signum (stereo microscope image).

Fig. 15. Male genitalia of *Rhodostrophia tyugui*, a junior synonym of *R. jacularia*. Valvae are spread open fully, i.e. pressed flat, unlike in Fig. 7. Juxta is attached to phallus (upper right hand corner) (photo and slide: S. Vasilenko).

Discussion

Thus far, the morphologically distinct females that have narrow wings and concave wing margins are known from a single population of *R. jacularia* only. The associated, reduced ability to fly need not be confined to the Altai mountains only, but it may be a more widespread phenomonon within this species. Even in the areas where females are fully-winged, the female ratio at light is usually low, about 10%, and it may be an indication of this. There are several examples known within Geometridae where females are fully winged but are reluctant to fly, e.g. *Lycia hirtaria* (Clerck, 1759) (Ennominae, Bistonini) and *Lipomelia subusta* Warren, 1893 (Sterrhinae, Scopulini).

We have shown that variation in the external appearance of *R. jacularia* is a continuous character, ranging from light brown to red-brown (Fig. 6). Therefore we conclude that ground colour can not be used as a diagnostic feature to separate *R. tyugui* from *R. jacularia*. Further, the diagnostic difference of the costa margin of the male valva, i.e. the degree of the angle, as presented by Vasilenko (1998), depends on the angle from which the valva is examined. We consider this quantitative character artificial and uninformative at separating taxa at the species level (Figs. 7, 8). Similarly, the general appearance of the valva, including its shape and width, depends upon how the genitalia preparation has been made. If the valvae are partly spread open (judging from the angle that the ventral margins of the valvae create), as in Fig. 7, then they appear to be much narrower than if they are fully spread open (Fig. 15). Finally, as was expected, a continuous positive correlation was noted between specimen size and its genitalia. We infer this to explain the observed difference in size between types of *R. jacularia* and *R. tyugui*.

Because we have not found any other diagnostic differences in the genitalia structures between *R. jacularia*, *R. jacularia* ssp. *minor* and *R. tyugui*, we treat all these taxa as conspecific. The subspecies status of *minor* has been disputed already by Hausmann (2004), it is conformed and formally proposed here. It is also worth noting, contrary to Hausmann (2004) that vesica of *R. jacularia* is without cornutus. Apparently, he has mistakenly considered the sharp, elongated projection in the apical part of the phallus as the cornutus. Furthermore, the genitalia structures of the narrow-winged females from the Altai mountains match well with the genitalia of *R. jacularia* from other regions and we therefore consider them to be conspecific with the latter. The conclusion that the specimens from Altai are conspecific with *R. jacularia* is further

strengthened by the observation that the males in that region are fully-winged, agreeing with other material examined.

In a few instances there is a correlation between the female wing reduction and the tympanal organs. For example in *Phigalia* Duponchel and *Erannis* Hübner (Ennominae, Bistonini), vestigially winged females have reduced tympanal organs or the structures are absent altogether whereas in males these structures are fully developed (Cook & Scoble 1992). We did not find this in *R. jacularia*, both males and females have fully developed tympanal organs. The variation of the female wing shape in *R. jacularia* is exceptional within Geometridae. We suspect that the exceptional feature of the Altai specimens has developed as an adaptation to local, harsh environmental conditions.

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