Range dynamics of some nemoral species of Lepidoptera in the Russian Far East due to climate change

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Received 5 September 2021 │ Accepted by V. Pešić: 24 September 2021 │ Published online 28 September 2021.

Abstract

New finds of seven East Asian Lepidoptera species in the Russian part of the southern Priamurye (Amur Basin area) are presented. *Lobocla bifasciata* (Bremer et Grey, 1853) (Hesperiidae), *Acosmeryx naga* (Moore, [1858]) and *Rhagastis mongoliana* (Butler, [1876]) (Sphingidae) were found in the Amur Oblast° for the first time. *Ambulyx tobii* (Inoue, 1976) (Sphingidae) was first discovered in the Khabarovsk Kray; it was also found in the Chernigovsky district of the Primorsky Kray, northward from the previously known localities. New finds of very rare nemoral species, *Chrysozephyrus brillantinus* (Staudinger, 1887) (Lycaenidae) and *Clanis undulosa* Moore, 1879 (Sphingidae), in the Khabarovsk Kray are reported. It is shown that the subtropical and tropical species *Siglophora sanguinolenta* (Moore, 1888) (Nolidae), first collected in Russia in 2020, has successfully naturalized in the southern Khabarovsk Kray. New finds of these species indicate that the species have extended their ranges northward and naturalized in new areas. This has occurred due to climate changes in the Amur River basin over the past decades such as the rising average annual and average air temperatures during cold periods.

Key words: Hesperiidae, Lycaenidae, Sphingidae, Nolidae, new records, climate changes, Priamurye, Amur Basin area.

Introduction

Despite the relatively good knowledge of such Lepidoptera fauna representatives as Papilionoidea, Sphingidae, and some other Lepidoptera groups inhabiting the southern Amur Oblast° and Khabarovsk Kray (Streltzov et al. 2003; Dubatolov & Dolgikh 2007; Koshkin & Novomodnyi 2008; Streltzov 2014; and others), new species have recently been discovered in these territories. This can be attributed both to the non-uniform knowledge of the fauna in some regions and invasion of southern species that has probably occurred due to climate change.
Recent studies have shown that the average annual temperatures in the Amur River basin over more than a century (1891–2004) increased by an average of 1.3°C; the greatest contribution to it was made by higher winter and spring temperatures (2–4°C/100 years) (Novorotskii 2007). The average annual air temperature in the southern Khabarovsk Kray and the Jewish Autonomous Oblast’ was rising at a rate of 0.12°C per 100 years over the period of 1891–2011; this rate was almost twice as high as the global average rate (Novorotskii 2013). Meteorological data recorded over the past years (2006–2021) at various weather stations in the southern Primorsure confirm this trend (http://rp5.ru).

Global warming events trigger northward migration of nemoral insect species. Thus, a trend related to occurrence of East Asian Lepidoptera species in the south of the Russian Far East, which had never found there before, has intensified over the past two decades (Dubatolov 2021). Many of these species belong to the families Sphingidae and Noctuidae (s.l.), which can be explained by their good flight ability and migration propensity. For instance, the following representatives of the family Sphingidae have recently been recorded for the first time in the territory of the Russian Federation: Acosmeryx naga (Moore, [1858]) (Beljaev 2003), Ambulyx tobii (Inoue, 1976) (Koshkin & Bezborodov 2013), Parum colligata (Walker, 1856) (Koshkin & Kostyunin 2017), Acherontia styx Westwood, 1847 (Dubatolov & Yakovlev 2013), Psilogramma increta (Walker, 1865) (Spitsyn & Spitsyna 2021). Earlier, in 1975, Clanis undulosa Moore, 1879 (Dubatolov 2021) and a number of vagrant hawk moth species were first discovered in the Russian Far East.

The following noctuid species were found for the first time in the territory of the Russian Federation over the past decade: Risoba yanagita Nakao, Fukuda et Hayashi, 2016 (Beljaev & Velyaev 2016), Euplexidia angusta Yoshimoto, 1987 (Koshkin et al. 2021), Bertiola spacoalis (Walker, 1859) (Koshkin et al. 2021), Callopistria aethiops Butler, 1878 (Dubatolov 2021), Siglophora sanguinolenta (Moore, 1888) (Koshkin 2021). Oraesia excavata (Butler, 1878), Eudocima phalonia (Linnaeus, 1763), Ischhya manlia (Cramer, 1776), Serrodes campana Guenée, 1852, Artena dotata (Fabricius, 1794), Ophiusa tirhaca (Cramer, 1777), Bastilla arctotaenina (Guenée, 1852), Catocala nubila Butler, 1881, and other noctuid species were reported as species migrating to the southern Primorsky Kray (sometimes time of discovery being not indicated) (Kononenko 2010).

Most of the aforementioned hawk moth and noctuid moth species have appeared in the Russian Far East due to accidental migrations or were brought by typhoons from the main parts of their ranges lying to the south. Almost all species were found in the southern Primorsky Kray (except for Siglophora sanguinolenta, which was found in the southern Khabarovsk Kray). Four of these species have naturalized in the Russian Far East: Clanis undulosa, Acosmeryx naga, Ambulyx tobii, and Siglophora sanguinolenta. The latter species has not yet been found outside its original habitat, while the three other hawk moth species have significantly extended their ranges northward.

In addition to the species first discovered in the territory of the Russian Federation, other East Asian species of Lepidoptera whose northern limits of distribution had originally been located to the south (mainly in the southern Primorsky Kray) have extended their ranges over the past two decades. Thus, the hawk moth Sphecodina caudata (Bremer & Grey, 1852) was found for the first time in 2006 in the southern Khabarovsk Kray and successfully naturalized there soon after (Koshkin & Bezborodov 2019). In 2019, this species was recorded even further north (and west): in the southeastern part of the Amur Oblast’, where it has apparently settled as well. Along with the vicinity of Karapcha cordon in Khingan Nature Reserve (Koshkin & Bezborodov 2019), this species was also found in the Arkharinsky district of the Amur Oblast’ 9.5 km northwest of Gribovka village in the valley of the Srednyaya Ilga River (49°32'22.9" N, 130°17'44.0" E, 1 ♂, 8.06.2019, A.A. Kuzmin leg.).

The following representatives of the superfamly Papilionoidea can be mentioned: Satarupa nymphalis (Speyer, 1879) (first found in the southern Khabarovsk Kray in 2002) (Koshkin & Novomodnyi 2008) and Chrysoszephyrus brillantinus (Staudinger, 1887) (first discovered in the vicinity of Khabarovsk in 2007) (Koshkin & Streltsov 2007). Both of these species have successfully naturalized in the southern Khabarovsk Kray, while S. nymphalis also inhabits the Jewish Autonomous Oblast’ (Koshkin 2014). It should be noted that we do not take into account the many East Asian Lepidoptera species found in the Khabarovsk Kray and Amur Oblast’ over the past two decades, which most likely results from the fact that some Lepidoptera families (Noctuidae s.l. mostly) in these areas have been insufficiently studied until the early years of the 21st century.
The studies performed in 2021 have revealed new data on the finds of some Lepidoptera species belonging to families Hesperiidae, Lycaenidae, Sphingidae, and Nolidae in the southern Khabarovsky Kray and Amur Oblast’ outside their normal ranges. Detailed information about these species is presented below.

Material and methods

This article is based on specimens collected in several localities in the southern Priamurye (Fig. 1). All moth specimens were collected in the upper reaches of the Shivki River (Bikin district of the Khabarovsky Kray) at night, the DRL 250 W and LepiLed lamps being used simultaneously. Rhagastis mongoliana was caught in the Arkharinsky district at night using a DRL 125 W lamp; Acosmeryx naga was collected in the Blagoveshchensk district using a LepiLed light trap. Lobocla bifasciata and Chrysozephyrus brillantinus specimens were caught at daytime using entomological nets.

Figure 1. Distribution records of the some nemoral species of Lepidoptera in the southern part of the Amur region (Russia).

Most of the photographs were taken by E.S. Koshkin with using a Sony SLT-A65 digital camera with a Sony 2.8/50 macro lens. Photos of the specimens L. bifasciata and Rh. mongoliana were taken by A.A. Kuzmin with using a Canon EOS 5D Mark II digital camera with a MS Volna-9 2,8/50 macro lens.

Voucher material is deposited in the first author’s private collection, except for the specimens L. bifasciata and Rh. mongoliana that are kept in the A.A. Kuzmin private collection.

The data on air temperatures at Arkhara, Khabarovsk, and Bikin weather stations were taken from the Reliable Prognosis weather forecast web service (rp5.ru).
Results

HESPERIIDAE

*Lobocala bifasciata* (Bremer et Grey, 1853) (Fig. 2A)

**Material examined.** 2 ♂, Russia, Amur Oblast’, Arkharinsky district, 7 km N Tarmanchukan railway station, 49°14'14" N, 130°38'54" E, 380 m, 1.07.2021 (A.A. Kuzmin leg.).

**Remarks.** The species is reported for the Amur Oblast’ for the first time. The Arkharinsky district is the northernmost location in the species range. The specimens were collected in the mixed forest with *Tilia amurensis, Acer pictum, Pinus koraiensis* and *Alnus hirsuta* near the hill's top, and with *Eleutherococcus senticosus* and *Actinidia kolomikta* in the undergrowth shrub layer. It has been previously recorded in Primurye based on sparse finds made in the southern Khabarovsk Kray (near Khabarovsk and Bikin) and Jewish Autonomous Oblast’ (near Babstovo and Soyuznoe) (Yamauti & Novomodny 2000; Koshkin & Novomodny 2008; Koshkin 2014) (Fig. 1). In Priamurye, larvae presumably feed on *Lespedeza bicolor* (Fabaceae), which is widespread in the nemoral zone of the Russian Far East (Koshkin 2012).

LYCAENIDAE

*Chrysozephyrus brillantinus* (Staudinger, 1887) (Figs 2B, C)

**Material examined.** 3 ♂, 1 ♀, Russia, Khabarovsk Kray, Khabarovsk district, 2 km S Voronezhskoe–1 village, 48°36'08" N, 135°03'35" E, 180 m, 14–16.07.2021 (E.S. Koshkin leg.).

**Remarks.** For a long time, *Ch. brillantinus* had been known in Russia only for the southern Primorsky Kray. In 2007 and 2008, it was first discovered in the Khabarovsk Kray. Four specimens were collected in the area south of Khabarovsk (foothills of the Bolshoi Khekhtsir Ridge, vicinity of the 20th kilometer of the Khabarovsk–Vladivostok highway, 48°17'36" N, 135°04'01" E, 200 m) on a section of a dirt road passing through a broad-leaved oak forest (Koshkin & Streltzov 2007; Koshkin 2009). Nowadays, this habitat has been destroyed as a section of the A-370 «Ussuri» highway built in 2019 passes through it. No new data on occurrence of the species in the Khabarovsk Kray have been reported so far. In July 2021, a population was found near Voronezh Hills, north of Khabarovsk city (Fig. 1). Four specimens were collected on a dirt road in a broad-leaved oak forest within two days (July 14 and 16, 2021) in the period between 11.00 a.m. and 3.00 p.m. Importantly, Voronezh Hills have been a favorite place among Khabarovsk entomologists for collecting butterflies for about half a century. However, *Ch. brillantinus* has never been found here. The new location lies 35 km north of the previous one. The new find indicates that this rare species is slowly settling in the southern Khabarovsk Kray. The extension of its range is apparently limited by climatic factors only, since the host plant of larvae (*Quercus mongolica*) is widespread in the southern part of the Russian Far East, being one of the edificator species in broad-leaved forests.

SPHINGIDAE

*Clanis undulosa* Moore, 1879 (Fig. 2D)

**Material examined.** 1 ♂, Russia, Khabarovsk Kray, Bikin district, 8 km SE Boitsovo village, upper reaches of Shivki River, vicinity of Shivki scientific station of Institute of Water and Ecology Problems FEB RAS, 46°55'06" N, 134°23'04" E, 165 m, mixed coniferous-broad leaved forest, 30.06.2021 (E.S. Koshkin leg.).

**Remarks.** This Southeastern and East Asian species was recorded in the territory of the Russian Federation in 1975, when the first specimens were collected in the Khasan district of the Primorsky Kray (Dubatolov 2021). Later, it naturalized throughout almost the entire southern half of the Primorsky Kray, reaching the Spassk district in the north (Koshkin et al. 2015). A.V. Korshunov collected a female specimen in Khabarovsk city in late July 2014 (Koshkin et al. 2015). There have been no other reliable data indicating that the species inhabit Priamurye ever since. A male specimen was collected in the southern Khabarovsk Kray, in the Bikin district, in late June 2021 (Fig. 1). Since only sporadic finds were made in Priamurye (yet,
the collected specimens are in excellent condition), we can assume that the species is currently slowly naturalizing in this region. There is a record of one male specimen collected in the northwestern Jewish Autonomous Oblast' and stored in the Jean Haxaire collection (labelled «Amurland, Maly Khingan Mt., Oblutchie, 48.2 N, 130.767 E, 600 m, 1993-08-01, S. Andreev») (BOLD Systems 2021, public BIN SOWA537-06). According to S.A. Andreev (pers. comm., August 21, 2021), this label is erroneous, since he has not collected this species in Oblutchie town, only in the Khasan district of the Primorsky Kray. Larvae feed on Lespedeza bicolor (Fabaceae), which is widespread in the nemoral zone of the Russian Far East (Zolotuhin & Evdoshenko 2019).

**Ambulyx tobii** (Inoue, 1976) (Fig. 2F)

**Material examined.** 3 ♂, Russia, Khabarovsky Kray, Bikin district, 8 km SE Boitsovo village, upper reaches of Shvik River, vicinity of Shvik scientific station of Institute of Water and Ecology Problems FEB RAS, 46°55'06" N, 134°23'04" E, 165 m, mixed coniferous-broad leaved forest, 29.06–1.07.2021 (E.S. Koshkin leg.); 3 ♂, Russia, Primorsky Kray, Chernigovsky district, 4 km SE Merkusheva village, 44°21'50" N, 132°50'28" E, 230 m, mixed coniferous-broad leaved forest, 18.06.2021 (V.G. Bezborodov leg.).

**Remarks.** This East Asian species was first collected in the territory of the Russian Federation in the Khabarsky district of the Primorsky Kray in 2011 (Koshkin & Bezborodov 2013). Its population in Russia was increasing from year to year, and its range was actively extending northwards. Thus, in 2014, *A. tobii* was recorded in the Oktyabrsksky district of the Primorsky Kray; in 2015, it was found in the vicinity of Vladivostok and Ussuriysk (Koshkin et al. 2015). According to the observations made by E.S. Koshkin and V.G. Bezborodov, it was already a common species in the vicinity of Kaimanovka village (Ussuriysk district) in 2018: up to 20 specimens were attracted to a light source per night in early June. In 2021, *A. tobii* was found much further to the north: in the Chernigovsky district of the Primorsky Kray and the Bikin district of the Khabarovsky Kray (Fig. 1). All the specimens collected in the Chernigovsky district in mid-June were already heavily damaged, while moths sampled in the regions lying to the north (southern Khabarovsky Kray) in late June/early July were much better condition. Therefore, an assumption that the specimens collected in the Bikin district have migrated from the southern regions can be ruled out. Hence, *A. tobii* has extended its range by ~ 600 km northward over the 11-year period. Larvae feed on various *Acer* species; *A. mandshuricum* was mentioned for the southern Primorsky Kray (Zolotuhin & Evdoshenko 2019). According to the personal communication of A.A. Voronkov (August 31, 2021), he was rearing larvae on *A. pictum*, which has a very wide range in the southern Russian Far East. Meanwhile, in Japan, larvae feed on *Juglans ailantifolia* (An Identification Guide…, 2021), with *J. mandshurica*, which is widespread in the southern part of the Russian Far East, being its close relative. It is possible that *A. tobii* larvae are oligophagous and can feed on different families of plants. The morphology of the immature stages of *A. tobii* has not been described yet. However, the larvae shown in photo no. 13 (plate 15) in the book by Zolotuhin and Evdoshenko (2019) does not belong to the *A. tobii* species but is a colored form of *Callambulyx tatarinovii* (Bremer & Grey, 1853). Taking into account the dynamics of northward range extension of *A. tobii*, the number and condition of the collected specimens, and the presence of host plants of larvae, it is fair to say that the species is currently actively naturalizing in the western Primorsky Kray and the southern Khabarovsky Kray. If the climate warming trends persist, one should expect further northward range extension of *A. tobii*, at least to the vicinity of Khabarovsky city, whose climatic parameters are similar to those of the Bikin district of the Khabarovsky Kray and western Primorsky Kray.

*Acosmeryx naga* (Moore, [1858]) (Fig. 2E)

**Material examined.** 2 ♀, Russia, Amur Oblast’, Blagoveshchensk district, Mokhovaya Pad’ village, 50°23’ N, 127°37’ E, 200 m, oak-deciduous forest, 3.07.2021 (V.G. Bezborodov leg.).

**Remarks.** The species was first recorded in the territory of the Russia Federation in 2002; the first finds were made in the Khasan and Ussuriysk districts of the Primorsky Kray (Beljaev 2003). Later, *A. naga* widely extended its range and naturalized in the southern Primorsky Kray. There are data on finds of species in the Spassk, Lazovsky and Shkotovsky districts (Tshitjakov 2009; Koshkin & Bezborodov 2013; Pittaway...
The two male specimens collected in the vicinity of Blagoveschensk is the first record of *A. naga* in the Amur Oblast’ and Priamurye in general (Fig. 1). It is not clear yet whether these specimens are migratory or naturalization of species has begun in the Middle Priamurye. Larvae in the Primorsky Kray feed on *Vitis amurensis* (Vitaceae) and *Actinidia* (Actinidiaceae) (Omelko & Omelko 2008; Pittaway & Kitching 2021). These plants also grow in Priamurye as well. Therefore, winter air temperatures and snow cover depth, which affect the overwintering success for pupae, can be the main factors determining the northward extension of the *A. naga* range.

**Rhagastis mongoliana** (Butler, [1876]) (Fig. 2G)

**Material examined.** Russia: 2 ♂, Amur Oblast’, Arkharinsky district, 4.5 km NW Rachi railway station, 49°17′19″ N, 130°24′42″ E, 250 m, 3.07.2021 (A.A. Kuzmin leg.); 2 ♂, Khabarovsk Kray, Imeni Lazo district, 25 km SE Durmin village, upper reach of Durmin River, 47°54′ N, 136°02′ E, 205 m, 27–31.07.2011 (E.S. Koshkin leg.); 3 ♂, Khabarovsk Kray, Bikin district, 8 km SE Boitsovo village, upper reaches of Shivki River, vicinity of Shivki scientific station of Institute of Water and Ecology Problems FEB RAS, 46°55′06″ N, 134°23′04″ E, 165 m, 1.07.2008 (E.S. Koshkin leg.); 2 ♂, same locality and collector, 26.06.2021; 2 ♂, same locality and collector, 23–29.07.2021.

**Remarks.** This species was discovered in the Amur Oblast’ for the first time. The find from in the vicinity of the Rachi railway station is the northernmost location in the species range. Two males were collected in the oak forest (*Quercus mongolica*) with an admixture of *Betula platyphylla*, and with *Juglans mandshurica*, *Corylus sieboldiana*, and *Eleutherococcus senticosus* in the undergrowth shrub layer. The species had previously been recorded in Priamurye only in the southern Khabarovsk Kray: the vicinity of Khabarovsk (Dubatolov & Dolgikh 2007), Anyuysky National Park (Dubatolov 2020), Imeni Lazo district, and the Bikin district (new records) (Fig. 1). The species is more common in the Primorsky Kray. Larvae feed on *Vitis amurensis* (Vitaceae).

**NOLIDAE**

**Siglophora sanguinolenta** (Moore, 1888) (Figs 2H–J)

**Material examined.** Russia, Khabarovsk Kray, Bikin district, 8 km SE Boitsovo village, upper reaches of Shivki River, vicinity of Shivki scientific station of Institute of Water and Ecology Problems FEB RAS, 46°55′06″ N, 134°23′04″ E, 165 m, mixed coniferous-broad leaved forest: 2 ♂, 1 ♀, 5–7.08.2020 (Koshkin 2021); 1 ♂, 26.06.2021 (E.S. Koshkin leg.); 1 ♀, 2.07.2021 (E.S. Koshkin leg.); 14 ♂♂, 24 ♀, 23–29.07.2021 (E.S. Koshkin leg.); 21 ♂, 1 ♀, 6–9.09.2021 (E.S. Koshkin leg.); 1 ♂, 26.09.2021 (E.S. Koshkin leg.).

**Remarks.** The species was first recorded in the Russian Federation based on three specimens collected in the Bikin district of the Khabarovsk Kray in early August 2020 (Koshkin 2021) (Fig. 1). In 2021, several dozen specimens of different condition degrees, from damaged to completely fresh ones, were found in the same locality. For instance, more than 20 specimens were encountered within one night (July 27/July 28, 2021). This indicates overwintering success of *S. sanguinolenta* in the southern Khabarovsk Kray. According to the nearest weather station «Bikin», the average temperature of the cold period (October 2020 through March 2021) was −8.5°C; the absolute minimum temperature was −33.8°C, while the average snow cover depth was 13.9 cm (http://rp5.ru). All these facts, as well as the presence of *Quercus mongolica*, a host plant of larvae (Sohn et al. 2017), are indicative of successful naturalization of the species in Russia. *S. sanguinolenta* probably has two or three generations per year in the southern Khabarovsk Kray; the flight periods of these generations partially overlap and last from mid-June till late September. The main range of the species involves North India, Nepal, the Korean Peninsula, China (including Taiwan), and the Philippines (Kononenko et al. 1998). The vicinity of Wonsan city located in the southern part of North Korea had been previously known as the northernmost locality of the species (National Institute of Biological Resources of Korea 2021).
RANGE DYNAMICS OF SOME NEMORAL LEPIDOPTERA SPECIES IN THE RUSSIAN FAR EAST

Figure 2. Some species of Lepidoptera from Amur region (Russia): A – Lobocla bifasciata, 1.07.2021; B, C – Chrysozephyrus brillantinus, 16.07.2021; D – Clanis undulosa, 30.06.2021; E – Acosmeryx naga, 3.07.2021; F – Ambulyx tobii, 1.07.2021; G – Rhagastis mongoliana, 3.07.2021; H, I, J – Siglophora sanguinolenta (H, I – 25–27.07.2021, J – live specimen, 9.09.2021). A, B, D–J – upperside, C – underside. A–H, J – males, I – female. Localities: A – 7 km N Tarmanchukan; B, C – 2 km S Voronezhskoe–I; D, F, H–J – 8 km SE Boitsovo; E – Mokhovaya Pad”; G – 4.5 km NW Rach.

Discussion

The data presented here indicate the active northward range extension of some nemoral species of Lepidoptera, to the areas where they have not been found previously. Due to the large size and bright coloration of adult insects, Sphingidae and Papilionoidea have been among the best-studied Lepidoptera groups in the southern Priamurye for more than a hundred years (with interruptions). For this reason, they
can serve as model groups for studying the dynamics of species ranges, including the dynamics related to climate change.

Factors responsible for successful colonization of new territories by Lepidoptera species are as follows: the presence of host plants for larvae and survival of the overwintering stages, which depends on various climatic parameters, including the average and minimum air temperatures (especially during the cold period), duration of the period of subzero temperatures, and snow cover depth (if species overwinter in soil or forest litter). Representatives of the family Sphingidae colonize new territories at the highest rate as the imago of many species are able to migrate. Many Papilionoidea species extend their range at a slower pace because adults tend to be more sedentary. In our case, this can be clearly seen for the Loboeca bifasciata and Chrysozephyrus brillantinus species. They naturalize in new habitats provided that the necessary conditions are met.

The extension of northern range limit of Sphingidae and some other families over the past two decades correlates with climatic warming in the south part of the Russian Far East. As mentioned above, the average annual temperatures in the Middle Priamurye rise faster than those in the rest of the world. This trend has been observed over the past fifteen years too. According to the data from three weather stations located in the southern Priamurye near the main sites of specimen collection, the average air temperature over the past five cold periods (2016–2021) has increased by 0.5–1.6°C compared to the previous ten periods, while the average annual temperature rose by 0.4–0.8°C (Table 1). The highest warming rates are observed in the southern Khabarovsk Kray («Khabarovsk» and «Bikin» weather stations).

Table 1. The average annual and average air temperature during cold periods in 2006–2021 recorded at some weather stations in the study area (rp5.ru)

| Weather station (its synoptic index, geographical coordinates, and altitude above sea level) | Average air temperature (°C) for five cold periods (October through March) / average minimum temperature (°C) for the same period | Average annual air temperature for five years (°C) |
|---|---|---|
| Period | 1.10.2006 – 31.03.2011 | 1.10.2011 – 31.03.2016 | 1.10.2016 – 31.03.2021 | 2006 – 2010 | 2011 – 2015 | 2016 – 2020 |
| Arkhara (31594) (49,4° N, 130,1° E, 135 m) | –13,7 / –14,2 | –14,2 / –40,6 | –13,2 / –39,5 | +0,6 | +0,4 | +0,8 |
| Khabarovsk (31735) (48,5° N, 135,2° E, 76 m) | –9,9 / –10,7 | –10,7 / –41,2 | –9,1 / –39,5 | +2,6 | +2,3 | +3,1 |
| Bikin (31832) (46,8° N, 134,3° E, 68 m) | –34,0 / –33,4 | –33,4 / –41,2 | –30,8 / –38,1 | +3,1 | +3,1 | +3,6 |

According to model calculations and revealed warming trends, the average annual air temperature in the middle Priamurye may increase by 2°C by 2050, which will be equivalent to northward displacement of natural zones by 150–200 km a shift in mountainous regions by 150–200 m higher in altitude (Novorotskii 2013). In this case, one should expect that the northern range limit of many nemoral Lepidoptera species in Priamurye will extend in future.

Acknowledgments

The authors are grateful Sergey A. Andreev (Tula, Russia) for shedding light into the situation with erroneous indication of Clanis undulosa collected in the northwestern part of the Jewish Autonomous Oblast’ in the BOLD database. Special thanks go to Anton A. Voronkov (Vladivostok, Russia) for providing information on the host plant for Ambulyx tobii larvae based on his observations. The Ministry of Science and Higher Education of the Russian Federation supported this work (project No. 121021500060-4 to E.S.K., project No. AAAA-A20-120031990009-4 to V.G.B., and project No. AAAA-A19-119060590003-0 to A.A.K.). The studies were carried out using the resources of the Center for Shared Use of Scientific
Equipment «Center for Processing and Storage of Scientific Data of the Far Eastern Branch of the Russian Academy of Sciences», funded by the Russian Federation represented by the Ministry of Science and Higher Education of the Russian Federation under project No. 075-15-2021-663.

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