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Lepidopterans of the Lower Amur Region: Barriers of Fauna Change

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Abstract—Changes in Lepidoptera fauna (without moths) from Southern Primorye to the Amur River mouth have been analyzed. The most significant change in the south-to-north direction has been registered on the border of rich broad-leaved forests. It has been suggested to consider this area the northeastern border of the Amur–Manchurian (Stenopean or Palaearchaearctic) zoogeographic choron. The territory to the north of this border, in the nearby of the Amur River mouth, is inhabited by transitional fauna. The main faunistic barriers of different phenological complexes (spring, summer, and autumn) are different in their location.

Keywords: faunistic barrier, border, lepidopterans, the Amur region
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The fauna of lepidopterans in the south of the Russian Far East is thought to be thoroughly studied. Nevertheless, as of the early 21st century, Southern Primorye is the best-investigated area, while the southern parts of the Amur and Jewish Autonomous oblasts have been partially studied. The situation in the lower part of the Amur River basin is different. Macrolepidopterans have not been studied in either the outskirts of Khabarovsk or the Amur River valley between Khabarovsk and the Amur River mouth.

The northeastern border of the East Asian subregion of Palearctic runs along the lower reach of the lower Amur River. There are some other names of this choron: Palaearchaearctic, Amur, Manchurian, and Stenopean subregion [1–4]. In this work it is called the Amur–Manchurian choron. Other above-given names are suggested for a large territory of East Asia, to southern China and the Eastern Himalayas. Previously it has been demonstrated that this subregion is significantly smaller and does not include the Chang Jiang River basin [5–8]. According to many investigations of the 19th and 20th centuries, this subregion was regarded as the Manchurian subregion. In the middle 1960s, A.I. Kurentsov suggested that it should be considered the Amur subregion [2]. The name suggested in this article, the Amur–Manchurian subregion, is more precise for the territory of this choron.

The actual fauna of insects on the northeastern border of the Amur–Manchurian choron has not been studied. The border has been described differently: N.Ya. Kuznetsov suggested two variants of it, somewhat to the south of Khabarovsk and near the Amur River mouth [9]; A.I. Kurentsov extrapolated it to the border of rich broad-leaved forests [2], which, as the botanists found, runs to the village of Sofiisk along the right bank of the Amur River and to the village of Kiselevka on the left bank [10, 11]. Later, A.F. Emel'yanov assigned his Stenopean choron to the territory of the Ussuri River valley to Khabarovsk, while the Lower Amur River valley from Khabarovsk to Komsomolsk-on-Amur was considered a transitional territory between Stenopean and Eurosibirian chorons [3]. According to M. Udvardi, the northeastern border of the Manchu–Japaneese biogeographic province is near Komsomolsk-on-Amur [12]. O.L. Kryzhanovskii did not cover this issue [4]. The abovementioned research did not calculate the ratio between different faunistic complexes. During the analysis of bird distribution (an active migratory group), B.K. Shtegman published a map where he demonstrated that the entire territory of the Lower Amur Region was inhabited by two faunas, Chinese and Siberian. The former is dominant upwards of Komsomolsk-on-Amur and the latter one downwards from this city [13].

Therefore, at the early stage of this investigation in the Lower Amur Region, the exact location of the choron under study and the features of this important zoogeographic border in Russia were unknown. In order to solve this problem, the following tasks were set: (i) find out the Middle Amur reference fauna of lepidopterans inhabiting rich broad-leaved forests; (ii) discover the species composition of lepidopterans in all major regions along the lower reach of the Amur River; (iii) detect the barrier between the most significant faunisitic complexes, nemoral and boreal; (iv) check the territory for the presence of a transitional faunisitic complex; (v) find the limits for the

penetration of nemoral elements in the northern direction in the nearby of the Okhotsky District; (vi) discover regularities in the distribution of Lepidoptera complexes (spring and autumn) in the Lower Amur Region.

MATERIAL AND METHODS

The analysis was performed using the most understood Lepidoptera groups: leaf rollers (Tortricidae), pyralids (Pyraloidae), diurnal lepidopterans (Hesperioidea, Papilionoidea), geometrids (Geometridae), bombycoid lepidopterans (Hepialidae, Cossidae, Limacodidae, Zygaenidae, Thyrididae, Uranioidea, Drepanoidea, Lasiocampoidea, Sphingoidea, Bombycoidea, Notodontoidea, Lymatriidae, Arctiidae, and Syntomidae from Noctuoidea), and noctuids (Noctuoidea, including those singled out by different researchers: Nolidae, Erebidae, and Micronoctuidae). Microlepidoptera except of Tortricidae and Pyraloidea were excluded from the analysis, because data on their distribution are sparse and incomplete. Therefore, more than 3/4 of all lepidopterans inhabiting the territory under study were taken for the analysis.

The following key territories of the south of the Russian Far East were taken to study the main faunistic barriers (Fig. 1): (1) Southern Primorye, (2) outskirts of Khabarovsk, (3) Komsomolsky raion and part of Solnechny raion, (4) Ulchsky raion near the villages of Kiselevka and Tsimmermanovka located on the border of rich broad-leaved forests, and (5) the Amur River mouth in the vicinity of Nikolayevsk-on-Amur. Data on Southern Primorye are taken from the Catalogue of the Lepidopterans (Lepidoptera) of Russia [14] and from the collections of the Institute of Systematics and Ecology of Animals, Siberian Branch, Russian Academy of Sciences, Novosibirsk, including the author's private collections of 1979, 1985–1986, 1993–1995, 1999, as well as from some published data that have not been included into the abovementioned catalogue [15, 16]. The outskirts of Khabarovsk were investigated in 2005–2011 at the Bol'shekhekhtsyrskii Nature Reserve [17–30] with regard to data from previously published works [31–36]. Investigations in Komsomolsky, Ulchsky, and Nikolayevsky raions were carried out in 2006–2011 [37–45]. In addition, all the previously published data on diurnal lepidopterans [46–49] and the materials collected and published from the 19th century [31–35, 50] and later [51] were considered. It should be noted that the northeastern limits of 60% of the total number of species found in the Amur Region (more than 1100 species) were discovered for the first time. The history of investigation of lepidopterans in the region under study has been published earlier [37, 40–41].

The faunistic barriers were assessed by the method proposed by I.V. Stebaeva and M.G. Sergeeva [52, 53].

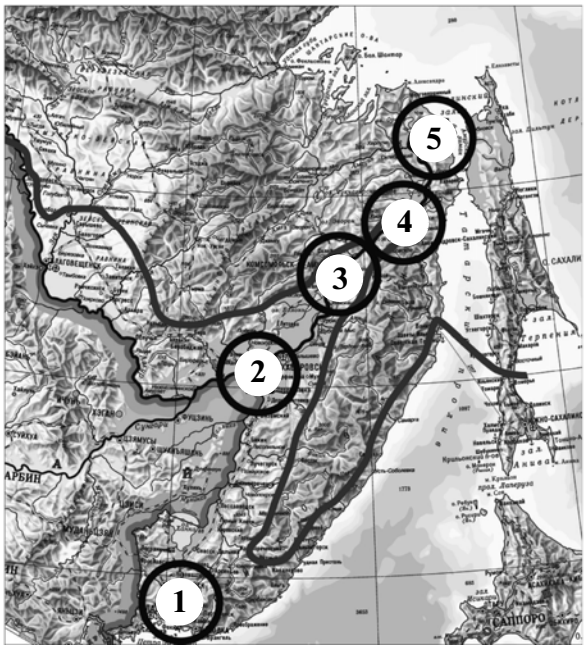

Fig. 1. Regions of the southern Russian Far East where zoogeographical analysis was performed: (1) Southern Primorye, (2) Khabarovsky raion, (3) Komsomolsky and Solnechny raions, (4) Ulchsky raion near the villages of Kiselevka and Tsimmermanovka on the border of rich broad-leaved forests, and (5) the Amur River mouth in the vicinity of Nikolaevsk-on-Amur and the northern part of Ulchsky District (Tyr). Here and in Figs. 4–5, the gray line is the border of rich broad-leaved forests, according to [10, 11].

Barrier efficiency is considered a ratio of the number of species that do not cross the barrier in either directions to the general number of species living on both sides of the barrier. In addition, the efficiency of barriers in one of the directions, understood as the ratio of the number of species that do not cross the barrier in one of the directions to the number of species living on the same side of the barrier, is applied. The barrier capacity is the number of species that do not cross the barrier.

SYSTEMATIC PART

Although the major materials were published in 2011, samples of several species which had been not registered earlier were collected the vicinity of Komsomolsk-on-Amur. The species are listed blow.

Family Epiplemidae

Dysaethria erasaria (Christoph, [1881]). 1 ♂, village of Pivan', August 14–15, 2011.

Family Noctuidae

Araeopteron koreana Fibiger et Kononenko, 2008. 1 ♂, village of Pivan', August 15–16, 2011. New species in Russian fauna; also collected: 1 ♂, Primorsky

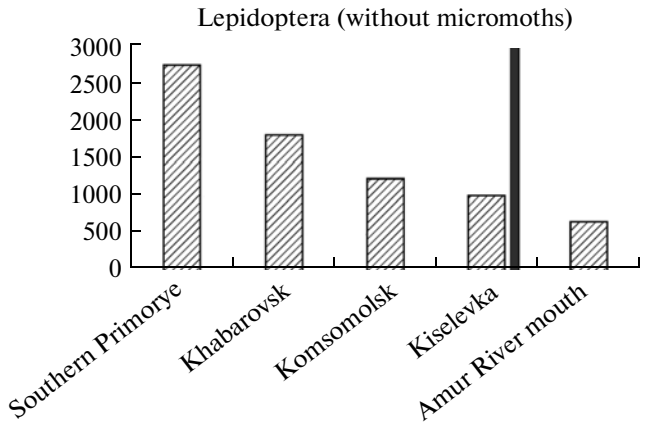

Fig. 2. Ratio of the total number of registered Lepidoptera species (without micromoths) in the local faunae in the southern Russian Far East. Here and in Figs. 3, 6, and 7, the gray vertical line is the border of rich broad-leaved forests, according to [10, 11].

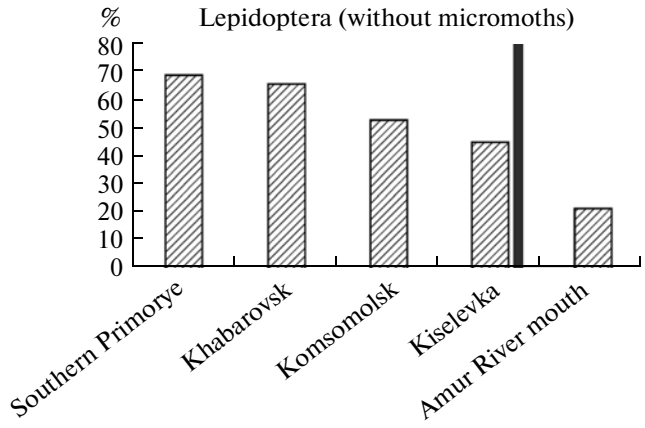

Fig. 3. Share of nemoral species in the local fauna of the southern Russian Far East.

Krai, 20 km southeast of Ussuriysk, village of Gornotaezhnoe, August 8–9, 1995, Dubatolov.

Amphipyra schrenckii Menetries, 1859. 1 ♂, village of Pivan', August 14–15, 2011.

Pyrrhidivalva sordida (Butler, 1881). 1 ♂, 1 ♀, village Pivan', August 14, 2011.

RESULTS AND DISCUSSION

If we accept habitat continuity and interpolate habitat distribution on intermediate points, it should be noted that Southern Primorye numbers more than 2800 species of lepidopterans (without micromoths); in Khabarovsky raion, a reference variant of the broad-leaved forest zone, there are more than 1800 species; in Komsomolsky raion there are more than 1250 species; in the vicinity of Kiselevka village there are more than 1000 species; and near the Amur River mouth there are 683 species (Fig. 2). At the same time, the share of subboreal or, to be more precise, almost completely nemoral species (from the group of amphipalaearctic, Amur–Manchurian, South Siberian–Amur species, as well as the species widespread in China and Japan) in the faunae of the key regions under study was high within the range of rich broad-leaved forests in the Amur River valley. In addition, it falls from 70 to 45% in the territory from Southern Primorye to the northeastern border of these forests. Near the Amur River mouth, the share of subboreal species is significantly lower (only 22%) (Fig. 3), but it is still three times higher than that of the discovered boreal taiga species (7%). The high share of nemoral subboreal species found near the Amur River mouth makes this fauna significantly different from any other Siberian fauna; a similar situation was observed north of the Bureinsky Mountain Range, where the family Tortricidae numbers only 17% of subboreal species [54], and in Eastern Transbaikalia [55]. The cluster analysis based on the data on the distribution of Tortricidae allowed grouping these faunae into special transitional clusters [56].

Therefore, the efficiency of the barrier between the Southern Primorye and Khabarovsk constitutes about one-fourth of all lepidopterans inhabiting this territory, between Khabarovsky and Komsomolsky Districts it was 38%, and between the outskirts of Komsomolsk and the village of Kiselevka it was 25%; the most significant barrier efficiency was found between the village of Kiselevka and the Amur River mouth: 45% (Fig. 4). If we consider separately the barrier efficiency in both directions, its values from the south to the north will be almost the same as that ones given above.

In the opposite direction, the efficiency of the barrier between the faunae of the Amur River mouth and the northern variant of rich broad-leaved forests is approximately 10% and between Kiselevka and Komsomolsky raion and between Komsomolsky and Khabarovsky raions it is approximately 6% each; the southward barrier is much weaker: less than 1.5% (Fig. 5). Values that are significantly lower than those obtained for the opposite direction can be ignored. The situation can be explained by the presence of the Sikhote-Alin mountain range, which is used by most boreal species to penetrate far south, to the Southern Primorye, Korea, and the East Manchuria Mountains.

To proceed with the comparison, one needs an area with common boreal fauna (also inhabited by temperate species), but such investigations of the main groups of lepidopterans have never been performed in the northern part of Khabarovsk Krai (Tuguro-Chumikansky and Ayano-Maysky raions). There are some representative collections only on diurnal lepidopter-

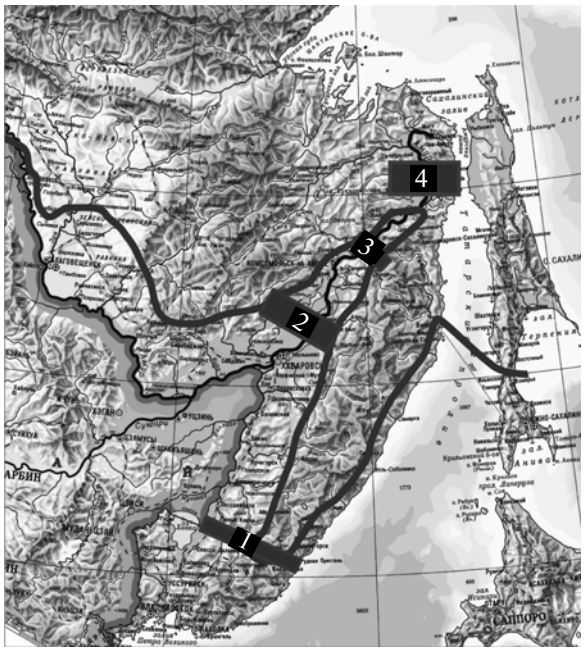

Fig. 4. Barrier efficiency in both directions and from the south to the north (in brackets): (1) between Southern Primorye and Khabarovsky raion, about 25%; (2) between Khabarovsky and Komsomolsky raions, 38%; (3) between Komsomolsky raion and the village of Kiselevka, 25%; and (4) between the village of Kiselevka and the Amur River mouth, 45%.

Fig. 5. Barrier efficiency in the north–south direction: (1) between Southern Primorye and Khabarovsky raion, <1.5%; (2) between Khabarovsky and komsomolsky raions, 6%; (3) between Komsomolsky raion and Kiselevka, 6%, and (4) between Kiselevka and the Amur River mouth, ~10%.

ans. The collections consist of 90 species and were sampled as early as 2009 [57]; among bombycoid lepidopterans, only single species are known [37]. If we extrapolate the Okhotsk fauna of bombycoid lepidopterans, based on the species inhabiting South Yakutia and the south of Magadan oblast (after the deduction of steppe inhabitants), the compiled list can contain about 80 species. In addition, the share of nemoral species among diurnal and bombycoid lepidopterans is extremely low here (less than 6%) [37]. Therefore, the efficiency of the barrier between the subnemoral fauna of the Amur River mouth and extrapolated temperate–boreal fauna can be about 45%, but this barrier should have lower capacity than that on the border of rich broad-leaved forests.

Attention should be also paid to the barrier along the Gur River, which was first discovered by F.R. Shtil'mark [58]. This may be where the northeastern border of at least 10 common Lepidoptera species goes: *Phyllosphingia dissimilis* (Bremer, 1861) (Sphingidae); *Caligula japonica* Moore 1862 (Saturniidae); *Uropiya meticulodina* (Oberthur, 1884); *Lophocosma atriplaga* Staudinger, 1887 (Notodontidae); *Gelastocera ochroleucana* Staudinger, 1887; *Diachrysia leonina* (Oberthur, 1879); *Cymatophoropsis trimaculata* (Bremer, 1861); *Meganephria cinerea* (Butler, 1881); *M. extensa* (Butler 1879); and *Tiliacea japonago* (Wileman et West, 1929) (Noctuidae). They were not found in Komsomolsky raion, i.e., only 100 km to the north. It is important that three of them are trophically bound to Manchurian walnut, which does not form any stands in the northward territories and grows here only as isolated trees. It can not be excluded that many species which have been considered uncommon northward of Khabarovsk should have their northeastern

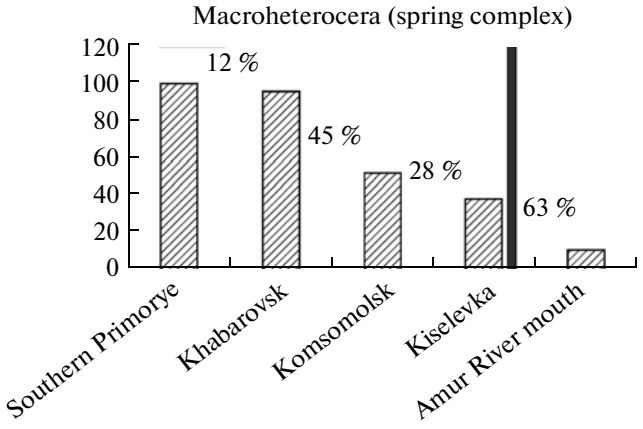

Fig. 6. Ratio of the number of obligatory spring species of Lepidoptera (without micromoths) in the local faunae of the southern Russian Far East. Numbers between the columns (here and in Fig.7) are the barrier efficiency for this complex of species.

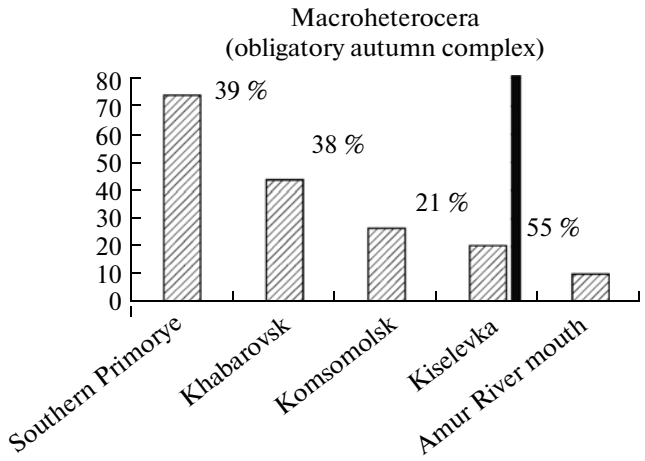

Fig. 7. Ratio of the number of obligatory autumn species of Lepidoptera (without moths) in the local faunae of the southern Russian Far East.

habitat border here. Nevertheless, in order to verify this assumption, stationary observations should be performed north of Nanaysky raion.

If we consider different phenological complexes, the above-described distribution will reflect the speciose summer complex. The complex of obligatory spring lepidopterans is marked only in higher nocturnal lepidopterans (Macroheterocera). This complex (Fig. 6) from the outskirts of Khabarovsk is slightly different in its species composition from that one of Southern Primorye, but in Komsomolsky raion the number of spring species significantly, by more than one-third, decreases. Further northwards, to the border of rich broad-leaved forests, the decrease in the number of spring species is less significant: only one-fourth of the species composition. If we consider such well-known group as Macroheterocera without Geometridae, the decrease will reduce to 15% [39]. In spring, the Lower Amur Region becomes a hard-to-reach area because of ice drift. However, this complex near the Amur River mouth should be at least twice as species-poor (based on currently available data).

The complex of obligatory autumn lepidopterans (Fig. 7) has been studied more thoroughly. Its species richness is highest in Southern Primorye, but it gets twice as poor in the vicinity of Khabarovsk and Komsomolsky District. Further to the border of rich broad-leaved forests, the degree of species poverty is less significant, and only single autumn species stay near the Amur River mouth. Higher requirements of autumn-active species to warmth and moisture content can be associated with the fact that their eggs are more sensitive to the cold drying in winter than the pupae of the species of spring complex wintering in shelters.

In southeastern Asia, higher nocturnal lepidopterans also have a winter phenological complex. Its most significant representatives are species of the genus *Pentateucha* Swinhoe, 1908 (Shingidae); the period of their activity lasts from December to February. This complex also includes a considerable number of species of Geometridae and Noctuidae. It vanishes in the territory near the south of the Russian border, on the southeastern border of Palearctic.

CONCLUSIONS

Thus, along the entire territory of the Lower Amur Region, from the southwest to the northeast, the Amur–Manchurian fauna disappears upon an insignificant and gradual (without a marked barrier) decrease in the number of boreal species. The greatest changes in the Lower Amur species composition were observed between the village of Kiselevka and the Amur River mouth. They are caused by the rich broad-leaved forests dying out. In addition, the Amur River mouth is also characterized by the subnemoral faunistic complex [59], which is still enriched by a marked but small number of the Amur–Manchurian species. This territory should be considered a transitional one between the two zoogeographical subzones. Its variant in the western part of the Amur River basin is the northeast of Amur oblast and East Transbaikalia, where a whole Amur–Manchurian complex of species was discovered earlier [54, 60, 61].

Different phenological complexes have their own faunistic barriers in Eastern Asia: for the spring complex the barrier goes between Khabarovsk and Komsomolsk-on-Amur, the autumn complex sharply gets poor to the north of Southern Primorye, and the winter complex disappears in central China. Since this regularity can be traced in all lepidopterans under study, it can be considered a general one.

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