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Analysis of Insect Distribution in the Northern Hemisphere by the Example of the Subfamily Arctiinae (Lepidoptera, Arctiidae). 2. Species Level

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Abstract—An attempt is made to apply cluster analysis to comparison of local faunas in the Northern Hemisphere at the species level by the example of the subfamily Arctiinae (Lepidoptera, Arctiidae). A total of 200 North African, Eurasian (New Guinea inclusive), and North American (north of the United Mexican States) local faunas have been considered. It is found that the circumarctic fauna is clearly separated from the Palearctic and Nearctic ones, being closer to the former only at the level of genera. Therefore, it is not reasonable to recognize the united European–Canadian subprovince of the boreal belt according to the tiger moth faunas. The Palearctic tiger moth fauna is characterized by relatively smooth variations within the boreal, subboreal, and western subtropical belts. The fauna gradually changes from the Amur catchment area to South China, Himalayas, and India so that all fauna types of these regions are closely related to one another and, to a lesser extent, to equatorial fauna types of Southeast Asia islands. The boundary between the Palearctic and Oriental (Indo-Malayan) provinces should be drawn north of the Yangtze catchment area. The most dramatic fauna change at the species level takes place between North China and the Yangtze catchment, and at the genus level, between Northern and Northeastern China. It is reasonable to establish a broad transition area between the two zoogeographic provinces in Eastern Asia. On the grounds of the nonuniform tiger moth fauna, the South Chinese–East Himalayan subprovince should be assigned to the Oriental (Indo-Malayan) province rather than the Palearctic one, as was repeatedly proposed. The Southwest-Asian fauna (Arabian Peninsula and southern Iran) is transitional between the Palearctic, African, and Oriental ones. Many African taxa penetrate to the west and south of the Arabian Peninsula, whereas Oriental and Paleotropical species penetrate to southern Iran. It is reasonable to elevate considerably the rank of the Quinghai–Tibet highland fauna by distinguishing its habitat as a separate zoogeographic subprovince, because the similarity between this fauna type and any other Palearctic fauna at the species level is much less than between temperate faunas of the Palearctic and Nearctic. The assignment of this fauna to the Palearctic is confirmed only at the genus level.

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This paper is a continuation of the formerly presented analysis of the distribution of the subfamily Arctiinae (Lepidoptera, Arctiidae) in the Northern Hemisphere at the level of genera [1]. It presents analysis of species distribution. The pattern at this level is less generalized and more detailed.

MATERIALS AND METHODS

The analysis was performed at the species level for the same 200 local faunas considered in the previous paper [1], where the genus level was discussed. The fauna similarity of the adopted geographical and topographical units was determined by the Jacquard coefficient [2]. The resulting data arrays were processed by cluster analysis with the proprietary factor classification program (KLAFA) developed at the Laboratory of Zoomonitoring, Institute of Animal Systematics and Ecology (IASE), and analyzed by the correlation-pleiades method [3–5]. The Jacquard coefficient is most commonly applied to analysis of areal fauna variability. One of its main features is that it takes into account depauperation as a feature of a local fauna.

RESULTS AND DISCUSSION

By using KLAFA, all the 200 local tiger moth faunas of the Northern Hemisphere were grouped into 31 clusters. They were adopted as fauna types. These clusters were arranged into one graph by the correlation-pleiades method. It allows discarding weak linkages between classes to maintain only significant ones [3]. In our study, the value of 16% similarity was taken to be the linkage significance threshold (Fig. 1). In cases of absence of such linkages, the strongest post-threshold linkages were used (shown with dashed lines). Fauna supertypes were determined as aggregations in the graph at linkage values above 15% of the similarity coefficient of separate faunas. These weak bonds are shown in dotted and short-dashed lines.

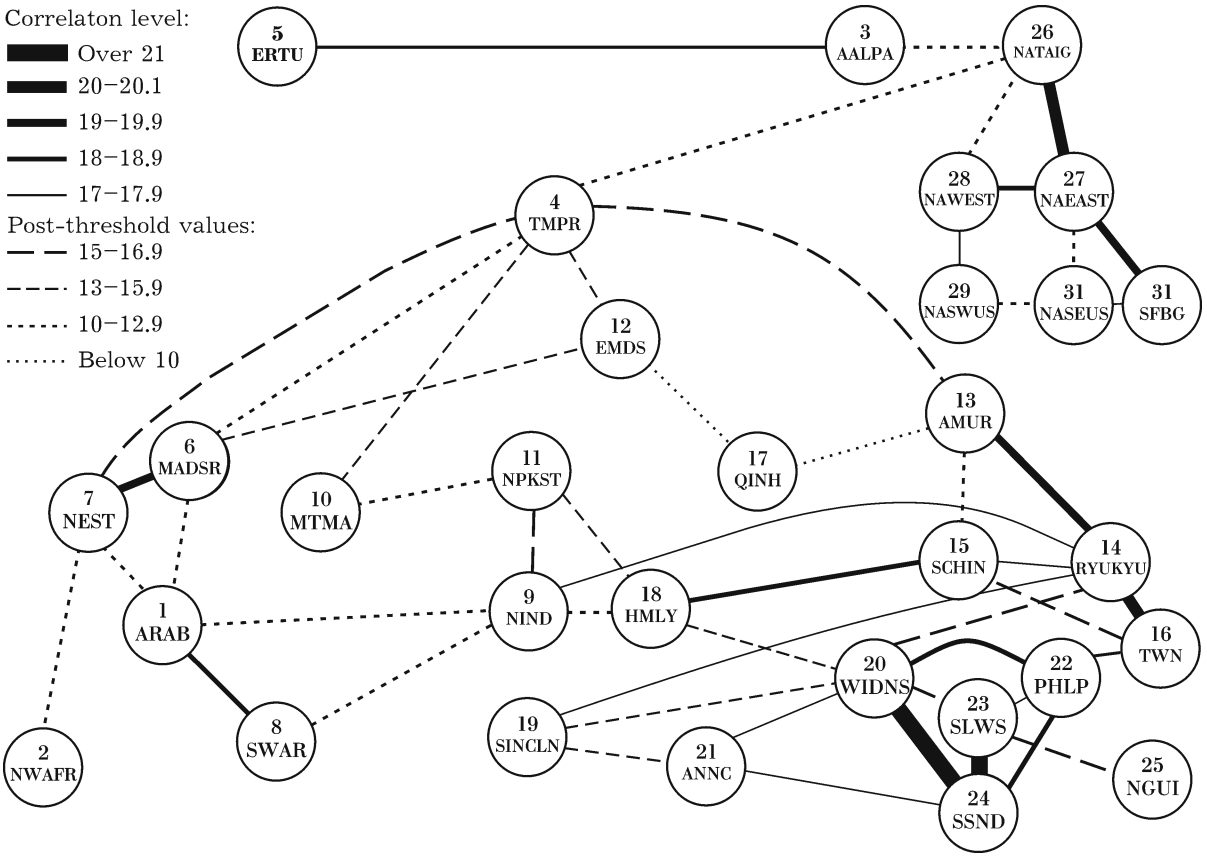

Fig. 1. Heterogeneity of tiger moth fauna in the Northern Hemisphere at the species level. Fauna similarities between regions are illustrated by proportional line thicknesses. The threshold is taken to be 16%. Post-threshold values are shown with dashed lines. Abbreviated fauna names: 1. ARAB, central and eastern areas of Arabia and the Persian Gulf; 2. NWAFR, Northwestern Africa; 3. AALPA, transarctic Eurasia and northwestern North America, northeastern Siberia mountains; 4. TMPR, temperate Eurasian fauna; 5. ERTU, tundras of European Russia; 6. MADSR, arid regions of Central Asia and the Caspian region; 7. NEST, Near East and southern Turkey; 8. SWAR, southwestern Arabia; 9. NIND, North India; 10. MTMA, mountains of Central Asia; 11. NPKST, mountains of northern Pakistan, Kashmir, and southeastern Afghanistan; 12. EMDS, Gobi deserts; 13. AMUR, middle Amur reaches, North China, and Japan; 14. RYUKYU, Ryukyu; 15. SCHIN, Central, East, and South China; 16. TWN, Taiwan; 17. QINH, Quinghai and Northern Tibet; 18. HMLY, Himalayas and Indochina; 19. SINCLN, South India and Sri Lanka (Ceylon); 20. WIDNS, Malacca and Greater Sunda Islands; 21. ANNC, Andaman and Nicobar Islands; 22. PHLP, Philippines; 23. SLWS, Sulawesi (Celebes); 24. SSND, Lesser Sunda Islands; 25. NGUI, Moluccas and New Guinea; 26. NATAIG, taiga of northwestern regions, Quebec, and Newfoundland; 27. NAEAST, eastern and central North American states; 28. NAWEST, western slope of Cordillera; 29. NAWUS, southwestern USA; 30. SFBG, southern Florida and the Bahamas; 31. NASEUS, Southeastern Texas.

The structural graph in Fig. 1 indicates that the faunas most isolated from other faunas of the Northern Hemisphere are those of Northwestern Africa, Arabia with Northeastern Africa and the coast of the Persian Gulf, the whole Transarctic region, North America (except for Arctic regions, Alaska, and Yukon), temperate Palearctic (temperate cluster), arid and highland regions of Southwestern and Central Asia (except for Arabia and adjacent regions), Gobi deserts (except for Dzungaria and Taklamakan), and Quinghai. Owing to considerable interpenetration of various fauna assemblages along the boundaries of zoogeographic provinces, the fauna of the Oriental province, including the catchment area of the Yangtze River, and Eastern Tibet form an integrated aggregation, which also includes the fauna of New Guinea.

On the basis of these data, classification of tiger moth faunas of the Northern Hemisphere was developed. Approaches to classifications of this sort should take into account the fact that unrelated faunas with few species of which one or two are endemic and other one or two are cosmopolitan can be combined in one cluster. Therefore, division of such clusters demands expert solutions. In our study, this was the case with the Canaries, whose fauna consists of two species. One of them forms an endemic genus (*Canararctia rufescens* Brulle), and the other (*Utetheisa pulchella*) is common in tropical and temperate regions of nearly whole Old World.

Names of **supertypes** are shown in boldface, <u>types</u> are underlined, and *subtypes* are italicized. Bracketed are abbreviations of corresponding types in the graph

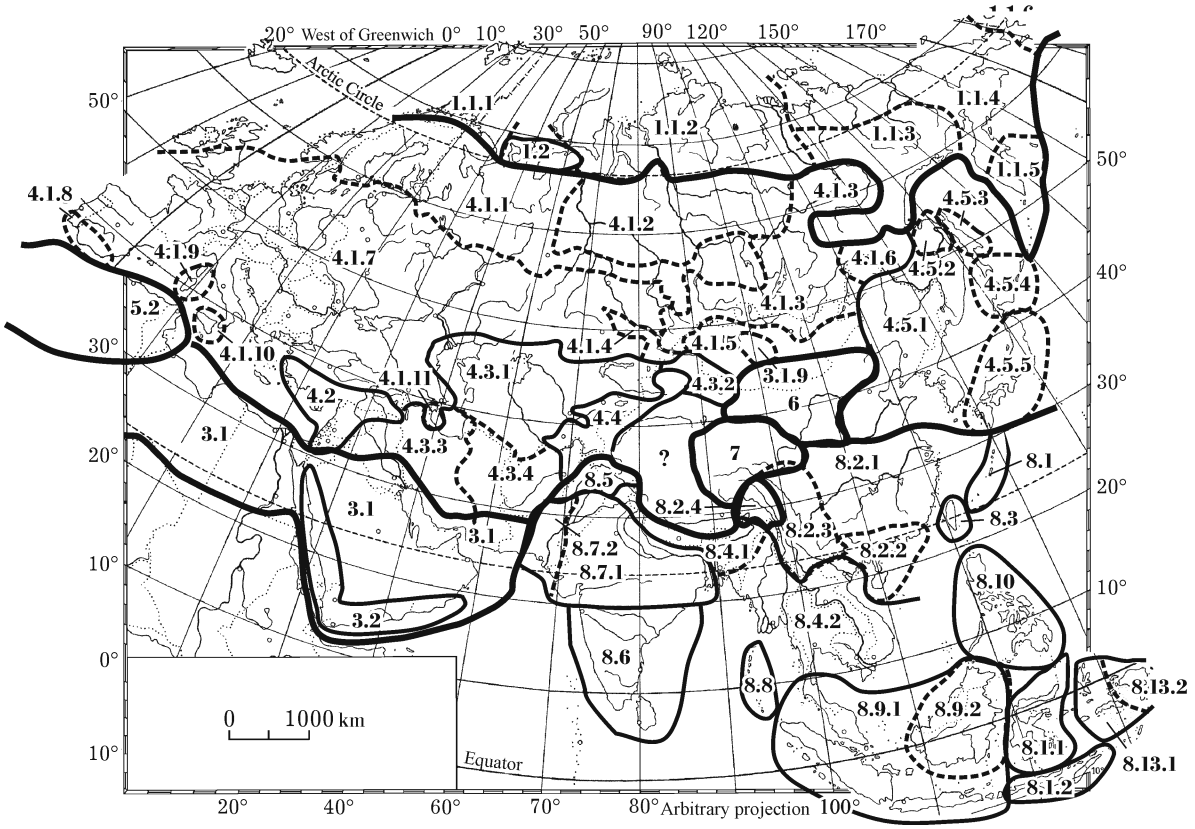

Fig. 2. Areal distribution of tiger moth fauna supertypes, types and subtypes in Eurasia and Northern Africa; species level. Designations follow the classification.

(Fig. 1). The areal distribution of fauna supertypes, types and subtypes is shown in Figs. 2 and 3.

1. **Arctic fauna supertype of Eurasia and North America, penetrating northwestern North American boreal areas**

1.1. Arctic fauna type of Fennoscandia, Siberia, and North America [3 AALPA]

Subtypes:

Arctic:

1.1.1. *Fennoscandia*

1.1.2. *West and Central Siberia*

1.1.3. *Yakutia highlands*

1.1.4. *Northeastern Siberia (Northern Yakutia, Chukotka, and Koryakia*

1.1.5. *Kamchatka*

1.1.6. *Alaska*

1.1.7. *North America without Alaska and Yukon*

Subarctic

1.1.8. *taiga areas of Alaska and Yukon*

1.2. Arctic fauna type of Eastern Europe [5 ERTU]

2. **Boreal-tropical supertype of North American fauna**

2.1. Boreal fauna type of North America (Northwest Territories, Quebec, and Newfoundland [26 NATAIG]

2.2. Subboreal-subtropical fauna type of eastern and central areas of North America [27 NAEAST]

Subtypes:

2.2.1. *highland of Cordillera (to the south from Yukon)*

2.2.2. *subboreal of southern taiga and subtaiga of northwestern North America*

2.2.3. *subboreal of northern prairies*

2.2.4. *subboreal-subtropical Alleganian*

2.3. Subboreal-subtropical fauna type of the western Cordillera macroslope [28 NAWEST]

Tropical fauna types:

2.4. Southern Cordillera (Sonora) [29 NASWUS]

2.5. Southern Florida and the Bahamas [30 SFBG]

2.6. Southeastern Texas [31 NASEUS]

3. **Subtropical-tropical fauna supertype of Arabia, Northeastern Africa, and the Persian Gulf coast**

3.1. Subtropical-tropical desert fauna type of central and eastern areas of Arabia, Northeastern Africa, and the Persian Gulf coast (1 ARAB)

3.2. Tropical fauna type of Southern and Western Arabia [8 SWAR]

4. **Temperate supertype of Eurasia, penetrating to western areas of the subtropical belt**

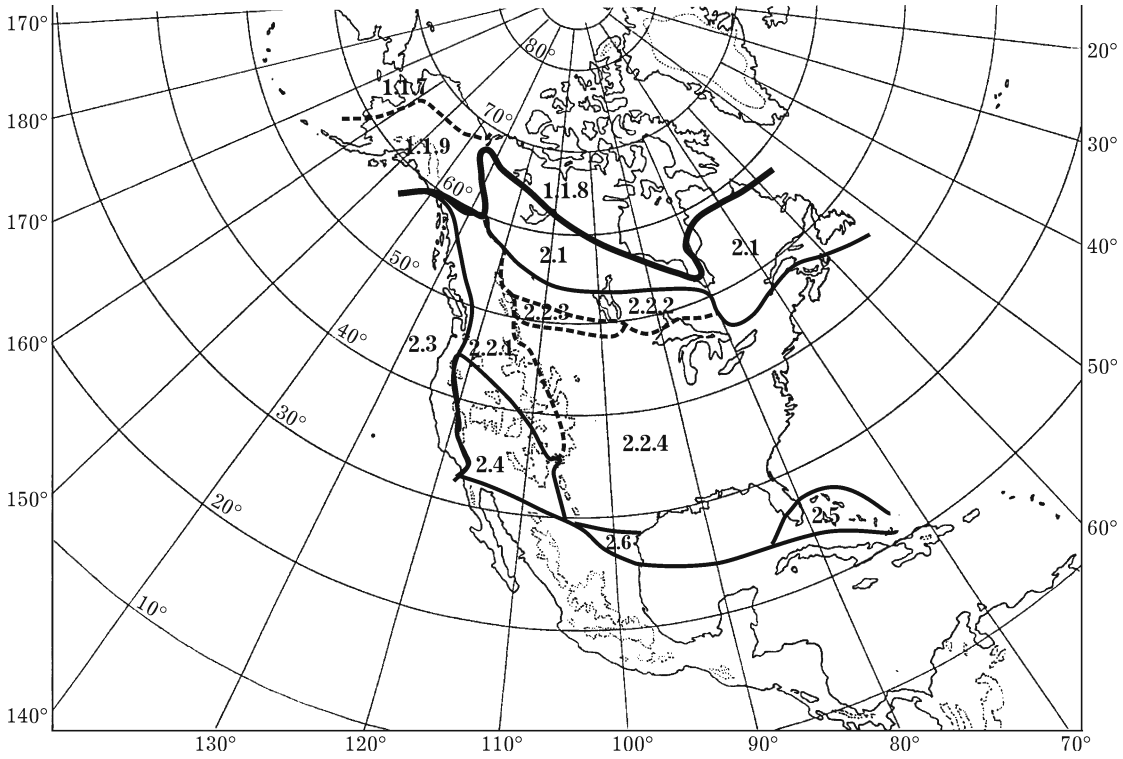

Fig. 3. Areal distribution of tiger moth fauna supertypes, types and subtypes in North America; species level. Designations follow the classification.

4.1. Temperate (boreal-subtropical) fauna type of Eurasia [4 TMPRT]

Subtypes:

boreal:

4.1.1 *Europe, south of West and Central Siberia*

4.1.2. *middle and northern taiga of West Siberia and Evenkia*

temperate:

4.1.3. *highlands of Southern Siberia, Northern Mongolia, and Central Yakutia*

subboreal:

4.1.4. *Tarbagatai, Dzungar Alatau, and Kazakhstan semideserts*

4.1.5. *Mongolian Altai and Mongolian semideserts*

4.1.6. *Upper Amur region*

subboreal-subtropical:

4.1.7. *Europe, Asia Minor, and West Siberia*

subtropical:

4.1.8. *southern Iberia*

4.1.9. *Corsica and Sardinia*

4.1.10. *Sicily*

4.1.11. *Talysh*

4.2. Subboreal fauna type of Levant [7 NEST]

4.3. Subboreal-subtropical arid fauna type of Southwestern and Central Asia [6 MADSR]

Subtypes:

subboreal:

4.3.1. *deserts of Southeastern Europe, Kazakhstan, and Central Asia*

4.3.2. *deserts of Northeast China*

subtropical

4.3.3. *Zagros Mountains including Northern Iran and Northern Iraq*

4.3.4. *Khorasan highlands, including Kopet Dag and Parapamiz*

4.4. Highland fauna type of Central Asia [10 MTMA]

Subtypes:

4.4.1. *northern and western Tien Shan*

4.4.2. *eastern Tien Shan*

4.4.3. *central Tien Shan*

4.4.4. *Pamir-Alai*

4.4.5. *Hindu Kush*

4.5. Subboreal-subtropical fauna type of the Amur region, Korea, and Japan [13 AMUR]

Subtypes:

subboreal:

4.5.1. *Middle Amur region, Primorye, Northeast China, and Korea*

4.5.2. *Lower Amur region*

4.5.3. *Northern Sakhalin*

4.5.4. *Hokkaido, Southern Sakhalin, and Southern Kuril Islands*

subboreal-subtropical:

4.5.5. *Honshu, Shikoku, and Kyushu*

5. **Subtropical fauna supertype of Northwestern Africa and Canary Islands**

Fauna types

5.1. Canary Islands (not shown in the graph because established by an expert decision)

5.2. Northwestern Africa (continental) [2 NWAFR]

6. **Subboreal fauna supertype of Gobi deserts [12 EMDS]**

7. **Highland fauna supertype of Quinghai [17 QINH]**

8. **Subtropical-equatorial fauna supertype of Eastern and Southern Asia**

8.1. Tropical fauna type of Ryukyu islands [14 RYUKYU]

8.2. Subtropical-tropical fauna type of China [15 SCHIN]

Subtypes:

8.2.1. *subtropical of the catchment area of the Yangtze River, including the Sichuan Basin*

8.2.2. *tropical of South China*

8.2.3. *highland of Western Sichuan and Yunnan*

8.2.4. *highland of Eastern Tibet*

8.3. Tropical fauna type of Taiwan [16 TWN]

8.4. Highland fauna type of Himalayas and Indochina [18 HMLY]

Subtypes:

8.4.1. *Himalayan*

8.4.2. *Indochinese*

8.5. Highland fauna type of southeastern Afghanistan, Northern Pakistan, and Kashmir [11 PKST]

Tropical fauna types:

8.6. South India and Ceylon [19 SINCLN]

8.7. North India, Southern Pakistan, and Southern Iran [9 NIND]

Subtypes:

8.7.1. *North India*

8.7.2. *Southern Pakistan-Southern Iran, or Makran*

Equatorial fauna types:

8.8. Andaman and Nicobar Islands [21 ANNC]

8.9. Malacca and Greater Sunda Islands

Subtypes:

8.9.1. *Malacca, Java, and Sumatra*

8.9.2. *Borneo*

8.10. Philippines [22 PHLP]

8.11. Sulawesi [23 SLWS]

8.12. Lesser Sunda Islands [24 SSND]

8.13. New Guinea and Moluccas [25 NGUI]

Subtypes:

8.13.1. *Moluccas*

8.13.2. *New Guinea*

This classification reveals features of the variability of local tiger moth faunas in the Northern Hemisphere. The circumarctic fauna is most notably different at the supertype level. It is characterized by relatively poor diversity (usually no more than 10 species) and presence of endemics, not found even in the alpine belt of mountains at lower latitudes (*Pararctia subnebulosa* Dyar, *Arctia olschwangi* Dubat., *A. opulenta* Hy. Edw., and *A. brachyptera* Troubr. et Lafont.). Many species do not penetrate the latitudinal or altitudinal forest belt, e.g., *Acerbia alpina* Quens. and *Holoarctia puengeleri* O.B.-H. This fauna has virtually no species that would inhabit also the forest belt and belts located farther south except for a single species, *Phragmatobia fuliginosa* L. The arctic supertype includes two main tiger moth fauna types. One of them includes arctic faunas of Fennoscandia, Siberia, and North America, including taiga areas of Alaska and Yukon. This type is represented by nine subtypes. The Fennoscandian subtype lacks the typical east Arctic species *Pararctia subnebulosa* Dyar, *Arctia olschwang*i Dubat., and all species of the genus *Dodia* Dyar.; therefore, it is similar to the Kamchatka fauna. The West and Central Siberian subtype is characterized by the absence of the East Siberian species *Hyperborea czekanowskii* Gr.-Gr. and circumarctic *Grammia quenseli* Payk. The Yakutia highland subtype includes faunas of all highland regions of Northeastern Siberia (except for Chukotka, Koryakia, and Kamchatka), and the Stanovoy Range. These faunas lack the arctic species *Arctia olschwangi* Dubat. but include *Hyperborea czekanowskii* Gr.-Gr., *Sibirarctia buraetica* O.B.-H., and *Epimydia dialampra* Stgr., whereas arctic *Pararctia subnebulos*a Dyar. penetrates to the Stanovoy Range. The Northeastern Siberian subtype includes faunas of Lower Kolyma reaches, Chukotka, and Koryakia. It is characterized by *Grammia quenseli* Payk. and absence of *Arctia olschwangi* Dubat. The Kamchatka subtype is close to the arctic fauna of Fennoscandia; the only difference is that it contains *Pararctia subnebulosa* Dyar. It was distinguished as a separate subtype by an expert decision because of being geographically remote. The arctic subtype fauna of Alaska differs from other arctic faunas in the presence of some North American species, e.g., *Arctia opulenta* Hy. Edw., and the presence of *Hyperborea czekanowskii* Gr.-Gr., which does not penetrate North America farther east. The North American tundra subtype is also distinguished by the presence of the endemic species *Arctia brachyptera* Troubr. et Lafont. The Subarctic fauna type of the taiga part of Alaska and Yukon is also very close to the mentioned arctic types, because typical arctic species *Grammia quenseli* Payk. and *G. philipiana* Ferg. penetrate there. For this reason, this subtype was not recognized as a separate type.

The arctic subtype of Eastern Europe is notably depauperated in comparison with not only the adjacent Arctic Urals but also with Fennoscandia. Only three species are recorded there: the tundra species *Pararctia lapponica* Thunb. and *Grammia quenseli* Payk. and the temperate species *Phragmatobia fuliginosa* L. in the south. This is caused by the absence of highland habitats and numerous species associated with highland tundras, common in Fennoscandia, Arctic Urals, and even in plain Siberian tundras. Because of this depauperation and the presence of one common temperate species, this type is similar to the poor fauna of Central Asian deserts. This depauperation may be due to historical causes. Probably, arctic species present in Fennoscandia but absent from modern Eastern Europe disappeared during the Holocene climatic optimum, when the tundra belt completely disappeared from continental Europe. In Fennoscandia, this tundra fauna survived only in highland areas.

The boreal-tropical supertype of North American tiger moth fauna includes six closely related types: boreal, western (confined to the western Cordillera macroslope) and eastern subboreal-subtropical, and three tropical types: South Florida, South Texas, and (the most detached) Sonora, confined to southern Cordillera and including both highland and tropical arid faunas.

Of special interest is the similarity (although post-threshold) between the North American boreal fauna (northwestern regions, Quebec, and Newfoundland) and the circumarctic fauna. It is determined by the presence of (1) the boreal-arctic species *Dodia albertae* Dyar, not found in the taiga belt of Europe, West Siberia, and East Siberia, and (2) both the boreal trans-Nearctic endemic *Platarctia parthenos* Harr. and temperate species of the genera *Grammia* Rbr. and *Holomelina* H.-S., which make the fauna close to the Alaskan taiga and Yukon faunas and, thus, to arctic faunas.

The fact that the eastern forest fauna, possessing many endemics and lacking tropical species, with moderately rich local faunas (about 35 species) reaches the Cordilleras in the west and forms an integral fauna type seems to be unexpected. However, it is quite natural, because there is no gap in the area of large-leaved tree species between the east and west of North America, in contrast to what is observed in Europe. The subtaiga forests and forest-steppe east of the Cordilleras in Canada are notably enriched in large-leaved trees, which matches the penetration of typical Alleganian tiger moth species, e.g., of the genus *Haploa* Hb. Although larvae of this genus are polyphagous, the area of the genus fits well in the area of the Allegan large-leaved flora. Also, xerophilic species are broadly represented in this area, e.g., the genus *Grammia* Rbr. They provide gradual transition to the Cordillera fauna. Only the fauna of western Cordillera slopes is notably more specific. The numbers of species in its local faunas are reduced to 27–34, which is much less than in the neighboring upper and eastern Cordillera areas. Thus, the subboreal-subtropical fauna type of eastern and central North America includes four subtypes: (1) the Alleganian fauna, represented by typical forest fauna with the genera *Haploa* Hb. etc., associated with subboreal large-leaved and subtropical humid forests of eastern North America; (2) the subtaiga forest fauna of northwestern North America, characterized by moderate penetration of Alleganian forest species, e.g., of the genus *Haploa* Hb.; (3) the fauna of northern prairies, characterized by lesser than in Cordillera contribution of arid species; and (4) the Cordillera fauna south of the Yukon, lacking Alleganian forest species but having more arid ones.

The South Florida-Bahamas fauna type includes many tropical species (*Utetheisa ornatrix* L., *Seirarctia echo* J. E. Smith, *Eupseudosoma involutum* Sepp, *Halysidota cinctipes* Grote, and *Composia fidelissima* H.-S.), not found even in Northern Florida but sometimes common with the fauna of the Antilles and Bahamas. The total number of species is relatively small (30), owing to the fact that this area is somewhat isolated. The most detached fauna types are two tropical ones. One of them, the Southeastern Texas fauna, is distinguished by a considerable proportion of arid tropical Mexican species and a moderate total number of species (37). The other fauna type, southern Cordillera, is characterized by an enormous number of arid tropical Mexican species (84).

Another important feature of the heterogeneity of local tiger moth faunas is that it varies insignificantly within the boreal, subboreal, and western areas of the subtropical belt in Eurasia. The range of species is relatively wide there (15–30). These species form the integral temperate (boreal-west-subtropical) fauna supertype. As a result, neither poor endemism of highland Alps and Caucasus areas nor significant endemism of Altai are pronounced even at the level of subtypes. Differences between boreal, subboreal, and, partly, subtropical Western Palearctic faunas can be traced only at the subtype level. This supertype includes five fauna types: temperate (boreal-subtropical) trans-Eurasian, subboreal-subtropical Amur-Korea-Japan, subboreal-subtropical arid Southwestern and Central Asian, highland Central Asian, and subtropical Levantine. The first four broad types include 4 to 11 subtypes.

Somewhat unexpectedly, the tropical fauna type of Southwestern Arabia does not form a separate supertype, in spite of the presence of numerous typical African tropical species (*Galtara somaliensis* Hmps., *Creatonotos leucanioides* Holl., and *Amerila vitrea* Plotz.), because this fauna is closely similar to those of Central and Eastern Arabia and the Persian Gulf. Even if African tropical regions are included in the analysis, they are recognized as a separate supertype because of the notable fauna diversity and distinctness with regard to the Southwestern Arabian fauna. Therefore, it is rea-

sonable to regard the fauna of the western and southern areas of Arabia as transitional between Afrotropical and Palearctic faunas. This fauna type is closest to the subtropical–tropical arid fauna type of the central and eastern parts of Arabia, Northeastern Africa, and the Persian Gulf coast, and the latter type is, in turn, similar to the Levant fauna and the subboreal-subtropical arid fauna type of Southwestern and Central Asia.

The aforementioned subboreal-subtropical arid fauna type of Southwestern and Central Asia is confined to arid areas of Central Asia and the Caspian region, from temperate deserts of Eastern Europe and Kazakhstan to Northern Iraq, Zagros Mountains, Southwestern Hisor-Darvaz, and Parapamiz. It is characterized by a set of specific arid species with the presence of other species, penetrating from the neighboring regions. It includes six subtypes. The subboreal fauna of deserts of Eastern Europe, Kazakhstan, and Central Asia is depauperated. It includes several arid species (*Lacydes spectabilis* Tausch. and others). The subtropical fauna subtype of Zagros Mountains, including Northern Iran and Northern Iraq, consists of a mixture of Southwestern Asian (e.g., *Euplagia splendidior* Tams and *Axopoena karelini* Men.), semiarid (*Lacydes spectabilis* Tausch., *Ocnogyna loewi* Zell., and *Nebrarctia semiramis* Stgr.) and Western Palearctic forest species (e.g., *Epicallia villica* L.). The subtropical fauna subtype of Khorasan mountains (including Kopet Dag and Parapamiz is depauperated in comparison with the fauna of Northern and Western Iran, but it also includes endemic (*Ebertarctia nordstroemi* Brandt) and Turan (*Eudiaphora turensis* Ersch.) species. The subboreal subtype of Northwest China deserts is similar to the first subtype but differs in the presence of one East Siberian-Mongolian steppe species (*Spiris bipunctata* Stgr.). This fauna type is also close to the local Levant fauna type (Southern Turkey and eastern Mediterranean coast), which is relatively poor (13–14 species) and includes endemics (*Cymbalophora oertzeni* Led. and *Ocnogyna bellieri* Led.).

The highland fauna type of Central Asia is markedly different from those above. It occurs in Tien Shan, Pamir-Alai, and Hindu Kush. It displays local endemism and includes five subtypes. Of these subtypes, the northern- and western Tien Shan ones are characterized by common highland species *Palearctia erschoffii* Alph., *P. gratiosa* Gr.-Gr., and *P. ferghana* Stgr. The eastern Tien Shan subtype occurs in the Chinese part of Tien Shan. It is characterized by considerable endemism (*Acerbia kolpakofskii* Alph. and *Palearctia rasa* Sald., Ivin. et Churk.). The central Tien Shan subtype is characterized by relative poverty and the presence of the endemic species *Palearctia wagneri* Pngl. The Pamir-Alai (mountains of Pamir-Alai and the Afghan part of Badakhshan) and Hindu Kush subtypes also display notable endemism (*Oroncus alaica* O.B.-H., *Nebrarctia guttata* Ersch., *Spilarctia melanostigma* Ersch., etc.) in Pamir-Alai mountains and as many as five endemic species in Hindu Kush.

The vast temperate Eurasian fauna type proved to be the most differentiated and the most separated. It includes 11 subtypes. The boreal fauna subtype of Europe and southern West Siberia also includes the faunas of Ireland, Scotland, Northeastern Altai, Kuznetsk Alatau, and Angara region. This subtype is characterized by absence of many subboreal species. The extremely broad subboreal fauna subtype of Europe and West Siberia includes the faunas of the bulk of Europe, Caucasus, Transcaucasia, northern Asia Minor, Southern Urals, and forest-steppe and steppe regions of West Siberia, including the Kazakh Uplands and Southwestern Altai. These regions have the widest range of species observed in these geographic belts. In contrast, the subtropical subtype of southern Iberia is characterized by notable endemism (*Coscinia romei* De Sagarra and *Hyphoraia dejeani* God.), including endemism at the genus level: *Artimelia* Rbr. The subtropical fauna subtype of Corsica and Sardinia is characterized by endemism, clearly pronounced against the background of certain depauperation: *Coscinia bifasciata* Rbr. and *Ocnogyna corsica* Rbr. The Sicilian subtype is also depauperated. It contains one North African species, *Coscinia libyssa* Pngl. The Talysh subtype is also depauperated in comparison with the neighboring fauna of Eastern Transcaucasia. The subboreal fauna subtype of Tarbagatai, Dzungar Alatau, and Kazakhstan deserts is a specific mixture of Turanian and Siberian species, not penetrating farther south. The boreal fauna subtype of middle and northern taiga of West Siberia and Evenkia is significantly depauperated (eight species), but it contains the transtaiga species *Borearctica menetriesii* Ev. Its difference from the corresponding belts of Europe is that many temperate species do not penetrate there.

The temperate fauna subtype of highlands of Southern Siberia, Northern Mongolia, and Central Yakutia contains a specific set of South Siberian species, e.g., of the genera *Sibirarctia* Dubat., *Chelis* Rbr., etc. The subboreal fauna subtype of Mongolian Altai and the Uvs Nuur Basin is similar to the previous one but differs in the presence of arid species, e.g., *Lacydes spectabilis* Tausch. and *Eudiaphora turensis* Ersch. The subboreal subtype of the upper Amur region is also a depauperated version of the fauna of South Siberian highlands, supplemented with Amur species: *Amurrhyparia leopardinula* Strand and *Phragmatobia amurensis* Seitz. Owing to the fact that the number of Amur species is small, this tiger moth fauna is closer to the Euro-Siberian rather than the East-Asian cluster. Apparently, in spite of the presence of Amur species (discussed in [6]), it can be combined with the Euro-Siberian fauna rather than Amur, and the boundary between the Euro-Siberian and Palearchearctic subprovinces of the Palearctic should be drawn at the boundary of occurrence of diverse large-leaved forests.

Particular attention should be given to the subboreal-subtropical fauna type of the Amur region, Korea, and Japan. It is formed by typical East Asian

nemoral species. The habitats of most of them fit well this territory. This fauna type includes five subtypes, four of which are subboreal: (1) Mid-Amur region, Primorye, Northeast China, and Korea (The penetration of Oriental species is insignificant, and certain endemism is observed: *Lemyra boghaica* Tshist. et Kishida.); (2) Lower Amur region (few species (14) and small proportion of East Asian species: *Diacrisia irene* Btl., *Rhyparioides amurensis* Brem., *Lemyra boghaica* Tshist. et Kishida); (3) Northern Sakhalin (narrow range of species (8) and only *Phragmatobia amurensi*s Seitz of East Asian species), (4) Hokkaido, Southern Sakhalin, and Southern Kuril Islands (the range of species is close to that of temperate forests, but the presence of Japanese endemics is notable, e.g., *Spilarctia obliquizonata* Miyake); and (5) subboreal-subtropical Honshu, Shikoku, and Kyushu (differs from the previous subtype in greater endemism, with species typical of the subtropical climate: *Eospilarctia lewisii* Btl., *Spilarctia graminivora* Inoue, and *Aloa lactinea* Cr., as well as some tropical migrants: *Nyctemera adversata* Schal., *Utetheisa pulchelloides* Hmps., and *U. lotrix* Cr.).

This type shows a threshold similarity (15%) to the temperate fauna type of Eurasia. Its similarity to the specific subtropical–tropical fauna type of China, occurring to the south, is much less (11%), but it is highly similar (19%) to the tropical fauna of Ryukyu Islands, which is also an individual type. However, this high similarity is related to the fact that the latter fauna is transitional between the Japanese one (the only East Asian subtropical fauna combining with the temperate belt fauna), entering this subtype, and the tropical Taiwan fauna, which forms an individual fauna type. Owing to the fact that the Ryukyu Island fauna is depauperated in comparison with the continent, and the Amur fauna of the temperate belt on the continent differs more from the subtropical fauna of the Yangtze catchment area than from the temperate fauna, it is decided to classify the Amur-Korea-Japan fauna type with the temperate Eurasian fauna supertype rather than with the supertype of Eastern and Southern Asia, with which it is closely linked through the depauperated Ryukyu fauna.

The subtropical fauna of Northwestern Africa, separated at the supertype level, forms two dramatically different fauna types: continental (relatively scarce, 12–16 species, but with a high endemism level) and Canary. Being greatly depauperated (only two species are known: *Utetheisa pulchella* L., commonly occurring in tropical and subtropical regions of the Old World and only one species of the genus *Canararctia* Dubat., endemic for the Canaries), this type was included by computerized classification to subtropical-tropical arid fauna type of Southwestern Asia (also notably depauperated), recognized as an individual type, and placed to the supertype under consideration by an expert decision.

Another feature of this classification is the clear separation of two Central Asian (in the narrow sense) faunas: Gobi and Quinghai, forming quite specific supertypes. The former includes only two species, one widely occurring (*Phragmatobia fuliginosa* L.) and one endemic of Gobi (*Centrarctia mongolica* Alph.), in contrast to the Dzungar fauna, where some desert species of the FSU part of Central Asia (*Lacydes spectabilis* Tausch. and *Eudiaphora turensis* Ersch.) penetrate, but *Centrarctia mongolica* Alph. is absent. The Quinghai fauna also includes the fauna of Gansu mountains. It is relatively poor (20 species) in comparison with the neighboring faunas (36 species in North China, 55 species in Southern Shaanxi and Eastern Sichuan, and 78 species in highland Western Sichuan) and displays the endemism level ranking among the highest in the Palearctic: above 10 species. Apparently, the fauna of the bulk of Tibet should be included there as well. Nevertheless, considering the fauna of the Tibet Autonomous Region of China as a whole, which has been well studied only in eastern areas and on the western slope of Himalayas, we see that it is extremely enriched in Oriental species, so it is combined with the fauna of the rest of Himalayas.

The most important feature of this classification is the combination of the whole subtropical-tropical Oriental-South Palearchearctic fauna of Eastern Asia (to the south from the Shandong Peninsula and Qinling Range) into a single tight cluster. It adjoins the fauna of North China, Amur region, Korea, and Japan with the linkage value 11.2%. This feature is related to the fact that a gradual transition from the large-leaved forest fauna, on the one hand, to the tropical forests (although their ranges of species are greatly different), on the other hand, exists in Eastern Asia, so that a wide mixed fauna zone, associated with this transition, exists in the Yangtze catchment area. It prevents the faunas of different zoogeographic provinces from separation, in contrast to the situation with the Palearctic and Afrotropical ecozones. I discussed the causes of this transition in [7]. Because of this transition, the location of the boundary between the zoogeographic provinces in Eastern Asia was always a matter of controversy, although the viewpoint that the boundary should be drawn in the very south China was predominant [8]. The data on Arctiinae distribution are in contradiction with this viewpoint. In my opinion, the boundary should be drawn much farther north: between the Shandong Peninsula and the Yangtze River, and in the west, along the Qinling Range. This opinion is in agreement with the viewpoint of Chinese scientists [9].

Thus, the subtropical–equatorial fauna supertype of Eastern Asia includes 13 types. The subtropical-tropical type of East China displays notable numbers of Oriental species, increasing to the south, in addition to species typical of nemoral forests and endemics of the Amur region. It includes four subtypes: the subtropical subtype of the Yangtze catchment area, including the Sichuan Basin (with maximum penetration of Pale-

arctic species and wider diversity than in North China with the presence of numerous Oriental species); the tropical subtype of South China (least penetration of Palearctic species and larger contribution of Oriental species than in the Indian subtype, with some endemism: *Kishidarctia klapperichi* Dan. etc.); the highland subtype of Western Sichuan and Yunnan (maximum range of species, both local and Oriental penetration of some Palearctic species to upper mountain belts); and the highland subtype of Eastern Tibet (the range of species narrower than in the previous subtype, but with a great contribution of East Himalayan species).

The highland fauna type of the Himalayas and Indochina is prominent in having a wide range of species and presence of endemics. It consists of three subtypes: East Tibet (with smaller contribution of Oriental species but with a greater proportion of highland Palearctic ones); Himalayan (the widest range of species in comparison with neighboring regions; many endemic species); Indochinese (no Palearctic species and much narrower range of species than in the Himalayan fauna subtype).

Two tropical fauna types are not divided into subtypes. They are insular: the Ryukyu type (depauperated range of species, typical of islands, with more than five species common with Taiwan and regions in the south and west, and the Taiwan type (insular depauperation in comparison with the proximal continental fauna is not pronounced, but clear endemism is observed). The North Indian type includes local faunas of Southern Pakistan and Southern Iran as an individual subtype. I considered the assignment of the South Iran fauna to Oriental in a special report [10]. This fauna type is a depauperated set of 8–9 Palearctic, Paleotropical, and Oriental (Southern Iran and Southern Pakistan) or 22 Paleotropical Oriental (Northern India) species. A similar fauna type (15% similarity) is the highland one of Southeastern Afghanistan, Pakistan, and Kashmir, which is formed by a mixture of Palearctic and Oriental species.

The tropical fauna type of South India and Ceylon is characterized by a greater number of species than the North Indian type, virtually all of them being characteristic of the Oriental province, and endemism, e.g., concerning the genera *Olepa* Wats., *Micraloa* Dubat., and *Tamilarctia* Dubat. It includes two subtypes: South Indian (wider range of species, above 50, with a small number of endemics, e.g., *Tamilarctia fumipennis* Hmps.) and Ceylon (much fewer species, 33, and pronounced insular endemism).

Six equatorial island fauna subtypes of Southeastern Asia stand apart. Some of them are recognized owing to endemism. Of them, only the type of Andaman and Nicobar Islands has as few as 8 species, whereas others are much richer, from 33 (Malacca Peninsula) to 56 (New Guinea) species. These are fauna types of Malacca and Greater Sunda Islands with two subtypes, of which one includes faunas of Malacca, Java, and Sumatra, and the other, Borneo; Lesser Sunda Islands; Sulawesi; New Guinea and Moluccas. These equatorial types form three groups: Andaman-Nicobar, West Sunda-Philippines, and Papua.

Thus, the heterogeneity of local tiger moth faunas in the Northern Hemisphere generally misfits the commonly adopted boundaries of zoogeographic units. The best agreement exists with the classical Kryzhanovskii [8] outline except for the recognition of the special Arctic fauna, occurring mainly in Arctic regions, and the Hyperborean (Arctic) subprovince of the Boreal province. However, the North American and Eurasian temperate faunas as well as the Arctic fauna have little in common (no more than 10–13%). Therefore, the single European–Canadian subprovince of the Boreal province recognized by Kryzhanovskii is not confirmed by tiger moth faunas.

Another important feature of tiger moth faunas is gradual change from the Amur catchment area to South China, Himalayas, and India, so that all fauna types in these regions are linked to each other and to equatorial types of Southeastern Asia islands. Therefore, the boundary between the Palearctic and Oriental faunas should be drawn farther northward than proposed by Kryzhanovskii [8]. Apparently, the rank of the Quinghai–Tibet highland fauna should be elevated, even by establishing its range to a special zoogeographic province, because the similarity between this fauna type and any Palearctic fauna is much less than between the temperate faunas of the Palearctic and Nearctic.

CONCLUSIONS

1. The distribution of tiger moth species in the Northern Hemisphere generally does not fit the commonly adopted zoogeographical divisions. Recognition of the special circumarctic fauna is in the best agreement with these divisions, whereas the North American and Eurasian nonarctic temperate faunas show only slightest similarity to both the arctic fauna and each other (no more than 6–8%). Therefore, it is not reasonable to recognize the integrated European-Canadian subprovince of the Boreal province according to tiger moth fauna. At the level of tiger moth species, separate circumarctic, Palearctic, and Nearctic faunas are distinguished. At the genus level, the circumarctic fauna is most similar to the Palearctic one, and at the species level, to Nearctic, but to a much lesser extent.

2. The Palearctic tiger moth fauna is characterized by relatively narrow variation within the boreal, subboreal, and western subtropical belts. Fauna features of Pyrenees, Alps, Caucasus, and even Altai with its considerable endemism are not traced even at the subtype level.

3. Another important feature of tiger moth distribution is the gradual change from the Amur catchment area to South China, Himalayas, and India, so that all

fauna types of these regions are closely related to each other and, somewhat less, to equatorial fauna types of Southeastern Asia islands. Therefore, the tiger moth fauna of the southern areas of large-leaved forests in the temperate belt of Eastern Asia does not differ much from the subtropical or tropical ones. It forms a cluster with the Oriental fauna, which is explained by the absence of significant latitudinal barriers in Eastern Asia. The boundary between the Palearctic and Oriental (Indo-Malayan) provinces should be drawn north of the Yangtze catchment area. At the species level, the most significant fauna change occurs between North China and the Yangtze catchment area, and at the genus level, between Northern and Northeast China. It is reasonable to establish a wide transitional area between the two zoogeographic provinces in Eastern Asia. On the basis of the heterogeneity of tiger moth fauna, the South China-East Himalayan subprovince should be considered to belong to the Oriental (Indo-Malayan) province rather than to the Palearctic one, as proposed earlier.

4. The fauna of Southwestern Asia (Arabia and Southern Iran) is transitional between the Palearctic, African, and Oriental ones. Many African taxa penetrate west and south of Arabia, and Oriental and Paleotropical species, invade Southern Iran.

5. It is reasonable to elevate the Quinghai–Tibet upland fauna in rank by establishing its range as a detached zoogeographical subprovince, because the similarity of this fauna type to any other Palearctic fauna at the species level is much less than between the temperate faunas of the Palearctic and Nearctic. The attribution of this fauna to the Palearctic province is confirmed only at the genus level.

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