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Understanding of Biogeography in the Palearctic and Indo-Malayan Regions Based on Larentiine Moths

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Cladistic biogeography is a method to search patterns of relationship among areas of endemism by combining cladistics with vicariance biogeography. There are three steps to find the relationships among areas: (1) constructing taxon-area cladograms based on taxon cladograms; (2) converting taxon-area cladograms into resolved area cladograms; and (3) generating a general area cladogram. Cladistic biogeography has been greatly advanced due to the recent developments in cladistics. The biota of the Holarctic and Indo-Malayan regions attracts many biogeographers, due to the size of the area, its diverse habitats and the great biological diversity in the Indo-Malayan region. However, the biogeographic patterns in large landmass such as the Holarctic region were poorly understood due to the difficulty of defining endemic areas, the lack of information, and the apparent dispersion across a continuous landmass. Also a general area cladogram for the Holarctic and Indo-Malayan regions is not available. At least three large-scale geological events are known to have influenced these areas: (1) three times of presence of the Turgai Sea separating the western and eastern Palearctic, 170/160- 130/120 million years ago (Mya), 105/95 - 70/60 Mya, and 60/53 - 37/30 Mya; (2) twice of the Atlantic bridge connecting the eastern Nearctic and western Palearctic, 148/138 - 138/130 Mya, and 70/60 - 20/12 Mya; and the great collision between the Indian subcontinent and Asia about 52 Mya, which brought dramatic geological and biological changes into the surrounding areas. The plants and animals in these areas were affected by these large-scale geological events, as well as by smaller scale events such as restricted glacial conditions during the Quaternary. The primary aim of this paper is to seek a hierarchical pattern among endemic areas in the Holarctic and Indo-Malayan regions based on larentiine moths. Using lepidopteran insects incldluing Geometridae in biogeography has several advantages since they are abundant and diverse and are easily sampled using light traps, prividing relatively comprehensive distributional data. Age of Geometridae is uncertain. Although fossils are too scarce to yield sufficient information to reveal the age and early evolution of the family, they do allow an estimate of the approximate time. The oldest lepidopteran fossils have been found in the Lower Jurassic and a fossil of the Geometridae was present in the Palaeocene (60 Mya). These fossil data suggest that early geometrid moths were flying at least 60 Mya. To define endemic areas, the smallest coincident ranges of two species was adopted as the main criterion and 11 areas of endemism were identified in the Holarctic and Indo-Malayan regions: northern India, southwestern Asia, central and southern Europe, northern Europe, south China, Taiwan, Russian Far East, Japan, Baikal area, western North America and eastern North America. Resolved area cladograms were produced with these 11 endemic areas and cladograms of seven genera of Geometridae: *Cidaria* Treitschke, *Thera* Stephens, *Pennithera* Viidalepp, *Heterothera* Inoue, *Callabraxas* Butler, *Gandaritis* Moore and *Eulithis* Hubner. Area relationships found are congruent with the current landmass configurations: (North America, (Europe, (northern India, (southwestern Asia, (Baikal area, (south China, (Taiwan, (Russian Far East, Japan). This area cladogram postulates at least three vicariance events: (1) North America - Palearctic; (2) western - eastern Palearctic; and (3) nothern India - the rest of Asia. However the present approach has several problems: the absence of a comparable general area cladogram, recent findings of inconsistency of biogeographic patterns from different analytical methods, ambiguous definition of endemic areas and taxon sampling, the presence of dispersal events and the collision betwen India and Asia. The collision between the Indian subcontinent and Laurasia created noise in the hierarchy of historical relationships of areas and thus the construction of hierarchical structure comprising the northern Oriental and Holarctic regions was considered as a difficult task by many biogeographers. Dispersal plays an important role in distribution, but this causes a methodological problem for cladistic biogeography. However, it should be noted that recognizing dispersals in the vicariance biogeographic study will reveal the real history of the organisms in the regions. In the present approach, several species were dispersed across endemic areas: from the Baikal area or south China to the Russian Far East; and from Russian Far East to Japan. Although the general aim of a modern biogeographic study is to find a congruent general area cladogram by mapping all living organisms, this approach seldom finds a congruent general area cladogram, due to different evolutionary time scales and diverse impacts on the organims. Therefore, the general area cladograms based on many animal and plant taxa in the Holarctic and Indo-Malayan areas would not be found. Instead of finding a general area cladogram in these areas, it will be more meaningful when the biogeographic pattern of a very spcific pattern by limiting the taxa like the geometrid species in the present study is corroborated by other taxa