Myrmecologische Nachrichten	8	239 - 249	Wien, September 2006

Ant (Hymenoptera: Formicidae) genera in southern China: Observations on the Oriental-Palaearctic boundary

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Abstract

To help draw the boundary between the Palaearctic and Oriental for ants (Formicidae) in China, distribution records were compiled. Of 67 Oriental genera in East Asia, 34 (51 %) reach no higher than 25° N, the median reach. Of 11 Palaearctic genera six (55 %) are known no further south than 31° N, the median reach for these taxa, and none south of 22° N. Richness of Oriental genera exceeded that of Palaearctic genera below about 37° N. Distribution data were organised by both 5° latitudinal band and by January mean minimum temperature band, and bands were compared using Simple Matching Coefficients of Similarity, non-metric Multidimensional Scaling, and cluster analysis. By all these approaches the greatest separation was around 25 to 26° N, but was disproportionately influenced by Oriental taxa. The proportion of East Asian Palaearctic genera exceeded the proportion of East Asian Oriental genera at around 28° N, where winter temperature is about 1 to 2° C. This approach, independent of genus richness of each component, suggests a Palaearctic-Oriental boundary close to the northern limit of the Mid-tropical Climatic Zone. By this boundary, some 10 % of East Asian genera are confined to the Palaearctic, 38 % to the Oriental, and 52 % common to both. Temperature tolerance is probably of prime importance in limiting the Oriental fauna, and altitude has a strong influence. Further work with altitude-referenced data is needed in the central China region.

Key words: Formicidae, ant genera, China, Oriental, Palaearctic, biogeography, latitude, altitude, temperature.

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Introduction

Biogeographers agree that southern China is an important interface between two great realms, the Palaearctic and Oriental (or Palaeotropical), but there are different perspectives on where the boundary lies. Vegetation maps conventionally define a coastal tropical belt within the palaeotropics up to 23 - 24° N, and a broader parallel subtropical one outside it, to around 33 - 34° N (HOU 1988, cited by W. ZHANG 1998). The zoogeographical system (ANON. 1979, cited by W. ZHANG 1998) used for herpetofauna (E.-M. ZHAO & ADLER 1993), and a similar system applied to agricultural and forest insects (S. ZHANG & ZHAO 1996), also recognise a narrow tropical belt and a broad central China subtropical region. Maps based on birds and mammals, which are relatively mobile and adaptable in response to temperature, can extend the Oriental into the northern part of the country, about one thousand kilometres to the north (CHENG & ZHANG 1959, S.Q. ZHAO 1986). HOFFMANN (2001) placed the boundary for mammals as a transitional zone between 33° N and 28° N, while the quantitative analysis of XIANG & al. (2004) suggested this northern (33° N) boundary to be most significant. Attempts to produce a zonation combining different vertebrate and plant taxa (MACKINNON & al. 1996, XIE & al. 2002) have also tended to result in two boundaries: a southern one demarcating the edge of the strictly tropical biota, and a northern one at the limit of the subtropical biota.

The taxonomic impediment prevents comprehensive analysis of most invertebrate groups at the species level, but genus-level patterns can be considered. Among ants, 112 genera are known from East Asia, most of which are concentrated in the Oriental; for ants the conventional Oriental realm is divided into a continental Oriental (roughly above 10° N) and an Indo-Australian or Malesian (BOLTON 1994). Characterising ant genus distributions becomes important when assessing endemism of different realms, or producing regional identification guides. It may also help ensure adequate biodiversity coverage of the protected-areas system (e.g., FELLOWES & al. 2004), and predict and monitor the impacts of climate change and invasive species.

The present paper explores different approaches to establishing an appropriate Palaearctic-Oriental boundary in China for ant genera. I draw on existing records, many of them scattered in the "grey literature"; I also make use of data collected during recent rapid biodiversity assessments – summaries of ecological and conservation characteristics for non-specialists, based on minimal sampling effort and cost (NEW 1998) – in South China (18 to 25° N, 105 to 114° E). Due to limitations in the data available I pay particular attention to that part of China east of 107° E, i.e., excluding the complex landforms of Yunnan and far west Guangxi in southwest China.

Material and methods

For this assessment I have considered only genera which are known from East Asia and whose distribution is clearly concentrated in one or other of the eastern Palaearctic or eastern Oriental (sensu BOLTON 1994) realms. For an objective cut-off I have taken two latitudes as provisional extremes of the transitional zone, representing the midpoints of each realm: 40° N for the northern limit (the classical limit to the subtropics, and roughly midway between the Arctic Circle and the Tropic of Cancer), and 16° N for the southern (midway between the southern tip of Indochina and the Tropic of Cancer). Excluded from the assessment are all genera whose ranges surpass both of these limits (*Amblyopone, Aphaenogaster, Bothriomyrmex, Cardiocondyla, Chalepoxenus, Crematogaster, Cryptopone, Dolichoderus, Hypoponera, Lepisiota, Monomorium, Myrmecina, Oligomyrmex, Paratrechina, Pheidole, Plagiolepis, Ponera, Pristomyrmex, Stenamma, Strumigenys, Technomyrmex, Tetramorium*, and *Vollenhovia*), as are those recorded only from north of the Palaearctic midpoint (*Alaucopone, Alloformica, Formicoxenus, Rossomyrmex*) or south of the Oriental midpoint (*Euprenolepis, Proatta*). Also excluded are genera confined to the southern Palaearctic and northern Oriental (*Dacatria, Linepithema, Liometopum, Perissomyrmex*), which cannot be assigned to either realm.

In some cases the taxonomy is not resolved at the genus level. *Emeryopone* was synonymised with the neotropical *Belonopelta* (BARONI URBANI 1975); the subsequent revival from synonymy (BOLTON 1995) was justified on the basis of an unfinished study by W.L. Brown Jr., but the name *Emeryopone* is retained here due to its wide acceptance in Asia. Most or all of the Chinese species of *Solenopsis* were reportedly referred to *Diplorhoptrum* by BARONI URBANI (1995, paper not seen), but it has not been possible to check my (mainly unidentified) specimens, or past China records, against this. The validity of the genus *Pyramica* has recently been questioned (ANDRADE & BARONI URBANI 2005), while *Pachycondyla* is likely to be split into a number of genera in East Asia, some tropical and some more widespread (Chris A. Schmidt, University of Arizona, pers. comm., 4 July 2006).

The literature was scanned for records in the provinces and other administrative regions of China, and other East Asian countries where relevant, to reveal the latitudinal limit in East Asia. (For latitudes and longitudes, minutes are disregarded; thus 32° 50' N is here treated as 32° N). Literature was sampled through reviews (e.g., WU & WANG 1995, FELLOWES 1996, ZHOU 2001) and original papers, representing about 100 sources in all.

Within the southern area of Guangxi Zhuang Autonomous Region, Guangdong Province, Hainan Province and Hong Kong Special Administrative Region (here collectively called "South China"), where I have quite extensive first-hand data, my most extreme altitudinal records were noted for both Palaearctic and Oriental genera. In recording altitude I distinguish between records either side of 107° E, due to the higher altitudinal reach of tropical biota (including ants) to the west of this line. Much of the data was collected during rapid biodiversity assessments (e.g., K.F.B.G. 2001) by Kadoorie Farm & Botanic Garden (K.F. B.G.) in the natural forest areas of the region, during 1997 - 2000. This involved hand collection of ants, with limited opportunistic Winkler sifting, whilst walking through the most natural accessible forest as part of a team surveying for plants and other animals; in total this produced over 4700 altitude-referenced ant distribution records from 49 forest areas. Other data came from various forms of collecting in Hong Kong from 1990 to 2000, mainly during postgraduate research and a subsequent Biodiversity Survey for the Department of Ecology & Biodiversity, The University of Hong Kong, together yielding a similar order of magnitude of records (not stored in a database). Most of the reference material is currently kept in the collection at Kadoorie Farm & Botanic Garden, Lam Kam Road, New Territories, Hong Kong Special Administrative Region, China.

The combined number of distribution records (of variable precision) in China from literature and personal collecting is estimated at 10,000 or more. In China, unless the latitude was known (South China only) all records from a province were assigned to the median latitude of that province. Since sampling effort varies greatly between provinces, data were merged within each 5° latitudinal band, from Hainan Province and north-central Vietnam in the south (16 - 20° N) to the belt of provinces north of 40° N. The ant genus presence-absence data were compared among different latitudinal belts. Genera were presumed to have continuous distributions, such that presence was inferred in all bands within the recorded latitudinal limits.

For the genera in China, the data were also organised into bands of the January (cold-season) mean minimum temperature (from ANON. 2002). This enabled calculation of the median temperature band for each group, and the change in proportions of tropical and temperate taxa with temperature band.

To place the boundary of the Oriental and Palaearctic ant genera in East Asia, a number of points were considered:

1. The extreme northern reach of Oriental genera.

2. The median northern reach of Oriental genera (equivalent to the point at which over half the Oriental genera disappear).

3. The extreme southern reach of Palaearctic genera.

4. The median southern reach of Palaearctic genera (the point at which over half of the Palaearctic genera disappear).

5. The point, moving northward, at which the number of Palaearctic genera exceeds the number of Oriental genera.

6. The point, moving northward, at which the proportion of East-Asian Palaearctic genera exceeds the proportion of East-Asian Oriental genera.

7. The point at which adjacent latitudinal zones show the lowest similarity. Given the circumscribed list of genera, it was considered that the common absence of a genus was equally important as the common presence (cf. BARONI URBANI & BUSER 1976, LEGENDRE & LEGENDRE 1998, CLARKE & WARWICK 2001). Thus Simple Matching Coefficients of Similarity were calculated from the conventional formula (e.g., BARONI URBANI & BUSER 1976) and analysed.

8. The point at which the ant fauna shows the greatest overall separation between zones based on non-metric Multidimensional Scaling (MDS) (Primer v5, CLARKE & WARWICK 2001) to compare coefficients of similarity. An indication of the representativeness of the MDS plot was obtained in the stress value.

9. The point at which the ant fauna shows the greatest north-south division between zones based on cluster analysis of coefficients of similarity, using the group-average method (Primer v5, CLARKE & WARWICK 2001).

These similarity analyses were done on data organised by both 5° latitudinal band and January mean minimum temperature band (hereafter "winter temperature band").

Results

Sixty-seven Oriental genera have been recorded in the northeastern Oriental realm (Tab. 1). A number of Oriental genera reaching Indo-Burma (*Cladomyrma, Lasiomyrma, Lio-*

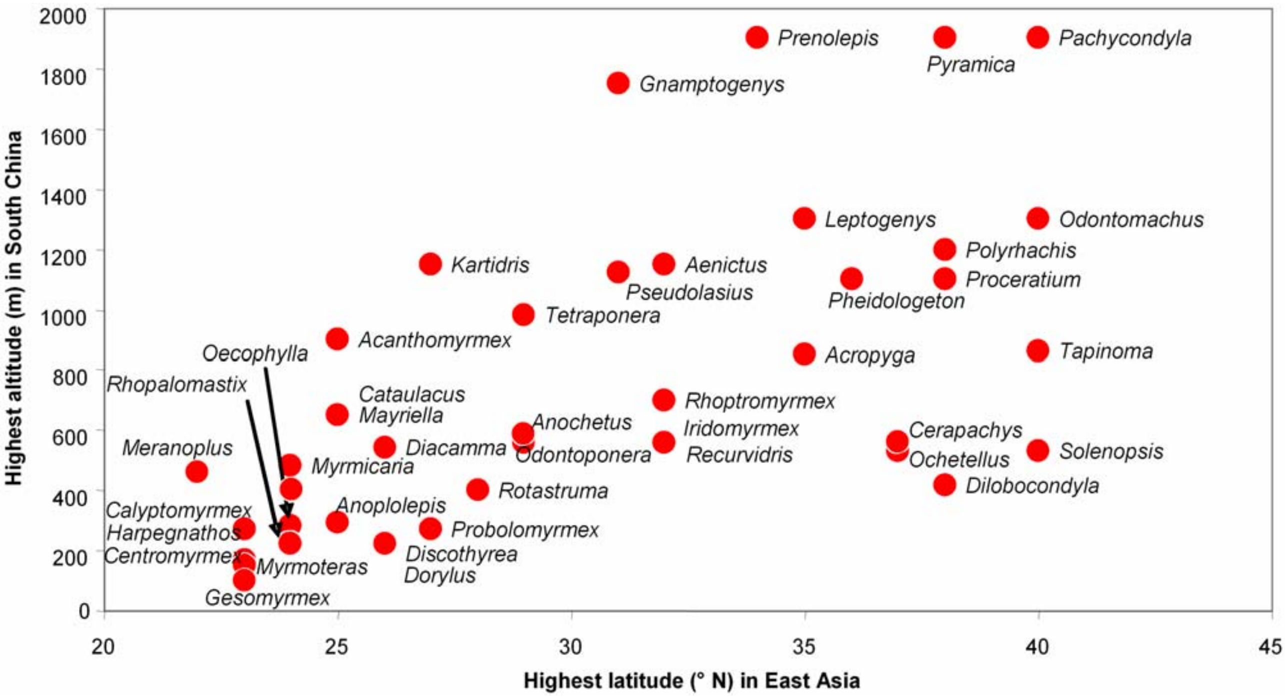

Fig. 1: Highest South China altitude record, and highest latitude record in the northeastern Oriental, for Oriental genera. South China is defined as 20 - 25° N, 107 - 114° E.

myrmex, *Myopopone* and *Sphinctomyrmex*) apparently do not reach as far as China, although some of these rare genera may not yet have been detected; *Anomalomyrma* and *Lordomyrma* are also known from Japan. Of the 60 Oriental ant genera recorded in China, not all are recently recorded in South China. Five (*Eurhopalothrix*, *Metapone*, *Paratopula*, *Prionopelta* and *Simopone*) have been recorded only in Taiwan, and not in the People's Republic of China (which includes Hong Kong and Hainan island). Three (*Bannapone*, *Platythyrea*, and *Protanilla*) are known in China only from Yunnan, while another two (*Lophomyrmex* and *Myopias*) are known from Taiwan and Yunnan but not South China. *Leptanilla* is known from Japan, Taiwan, Hunan and Yunnan. Of the genera previously reported in South China, *Anillomyrma* is known from a historical record in Guangdong; *Carebara* is known from an old record in Hong Kong and from south Yunnan, but not confirmed recently from South China. The remaining 46 genera have been recorded in South China in recent years. Table 1 gives the northernmost latitude at which they have been recorded, and my highest altitudinal record, in mainland South China (west and east of 107° E) and on Hainan island.

Recorded on mainland China but not yet the islands of Taiwan or Hainan are *Anillomyrma*, *Carebara*, *Gesomyrmex*, *Mayriella*, *Myrmicaria*, *Rhopalomastix*, *Rotastruma*, and *Vombisidris*. Recorded on the mainland and Hainan but not Taiwan are *Cataulacus*, *Dilobocondyla*, *Dorylus*, *Harpegnathos*, *Kartidris*, *Myrmoteras*, *Mystrium*, *Oecophylla*, and *Philidris*. Only *Centromyrmex* and *Myopias* have been recorded on mainland China and Taiwan but not on Hainan.

Of the 67 Oriental genera in the northeastern Oriental, 13 (19 %) have been recorded north of 35° N, 24 (36 %) beyond 30° N, 33 (49 %) beyond 25° N, and 64 (96 %)

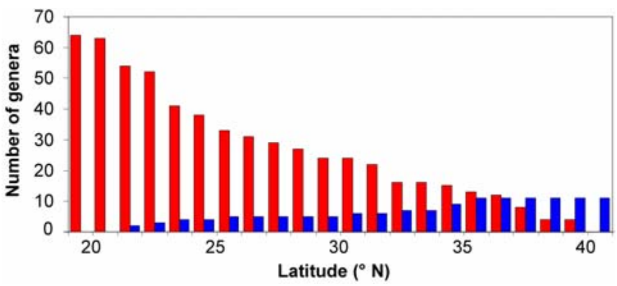

Fig. 2: Chart showing the number of East Asian Palaearctic (blue) and Oriental (red) genera occurring at different latitudes in eastern China.

beyond 20° N. The extreme northern reach is (by definition) around 40° N, where winter temperature is around -10 °C. The median northern reach is 25° N, where winter temperature is around 3 °C.

For 42 genera recorded in South China the latitudinal limits in East Asia, and altitudinal limits in South China, are shown in Figure 1.

Of the 11 "Palaearctic" genera recorded in the southeastern Palaearctic region, only *Manica* has not been recorded in China. No Palaearctic genera have been recorded in Hainan or Hong Kong (with the exception of historical reports of *Lasius* in both places, both apparently erroneous), and none south of 22° N, where the winter temperature is around 7.5 °C. Four (*Formica*, *Lasius*, *Temnothorax*, and *Myrmica*: 36 % of genera) have been recorded in South China, at or below 25° N, and the same four in Taiwan (Tab. 2). Five (45 %) are known at or below 30° N and eight (73 %) at or below 35° N. Table 2 gives the southernmost latitude at which each genus has been recorded in the southeastern Palaearctic, and the lowest altitude at which

Tab. 1: The recorded northern latitudinal limits in the northeastern Oriental, and highest altitudinal limits in South China, of Oriental ant genera. From the author's field surveys and the literature, with first records from each Chinese province or administrative region. Digital supplementary material at the journal's web pages provides full references for Tab. 1.

Genus	**Highest latitude (° N)**	**Highest altitude (m) recorded in South China**			**China provinces and regions recorded, and other records relevant to latitudinal reach**
		mainland, 20 - 25° N 105 - 106° E	**mainland, 20 - 25° N 107 - 114° E**	**Hainan island (18 - 20° N 108 - 110° E)**	
Acanthomyrmex	25	–	900	900	Taiwan, Hong Kong, Guangxi, Yunnan, Hainan, Guangdong
Acropyga	35	–	850	850	Taiwan, Macau, Hong Kong, Jiangxi, Guangxi, Shanghai, Yunnan, Hainan; central Japan
Aenictus	32	1060	1150	1310	Taiwan, Fujian, Guangdong, Yunnan, Guangxi, Sichuan, Hunan, Hubei, Anhui, Zhejiang, Jiangxi, Hainan, Guizhou, Fujian, Hong Kong
Anillomyrma	23	–	–	–	Guangdong
Anochetus	29	–	580	830	Hong Kong, Taiwan, Fujian, Guangxi, Yunnan, Zhejiang, Guangdong, Hainan
Anomalomyrma	38	–	–	–	no China records; north-central Japan
Anoplolepis	25	900	290	840	Guangdong, Hainan, Fujian, Hong Kong, Macau, Taiwan, Guangxi, Yunnan
Bannapone	21	–	–	–	Yunnan
Calyptomyrmex	23	1180	270	940	Hong Kong, Guangxi, Hainan
Carebara	22	–	–	–	Hong Kong, Yunnan
Cataulacus	25	1180	650	970	Hainan, Guangxi, Yunnan, Guangdong
Centromyrmex	23	–	170	–	Hong Kong, Taiwan, Yunnan
Cerapachys	37	1270	840	1200	Hong Kong, Taiwan, Zhejiang, Yunnan, Shanghai, Sichuan, Guangdong, Guizhou, Xizang, Guangxi, Hainan; Korea
Cladomyrma	20				N. Vietnam (Cuc Phuong)
Diacamma	26	930	840	760	Guangdong, Hong Kong, Fujian, Macau, Hainan, Taiwan, Hunan, Yunnan, Guangxi
Dilobocondyla	25	–	420	–	Fujian, Hainan, Guangxi, Hong Kong, Guangdong
Discothyrea	38	–	220	–	Taiwan, Hong Kong, Guangxi, Yunnan, Hunan; north-central Japan
Dorylus	26	–	220	–	Hong Kong, Fujian, Yunnan, Hunan, Guangxi, Guizhou, Hainan, Guangdong
Echinopla	21	–	? (< 600)	–	Yunnan, Guangxi
Emeryopone	21	–	–	–	Yunnan
Eurhopalothrix	23	–	–	–	Taiwan
Gesomyrmex	23	–	100	–	Guangdong, Hong Kong, Guangxi
Gnamptogenys	31	1030	1750	1360	Hong Kong, Taiwan, Guangdong, Guangxi, Hunan, Hubei, Sichuan, Yunnan, Hainan
Harpegnathos	23	430	270	40	Hong Kong, Macau, Yunnan, Guangxi, Hainan
Iridomyrmex	32	1050	560	790	Taiwan, Guangdong, Fujian, Hong Kong, Macau, Shanghai, Zhejiang, Anhui, Hunan, Guangxi, Yunnan, Hainan
Kartidris	27	–	1150	1090	Hainan, Fujian, Yunnan, Guangdong, Guangxi, Jiangxi
Lasiomyrma	21	–	–	–	no China records; N. Vietnam (Ha Tay)
Leptanilla	35	–	–	–	Hunan, Taiwan, Yunnan; Japan
Leptogenys	32	1740	1300	1260	Taiwan, Fujian, Hong Kong, Macau, Guangdong, Yunnan, Jiangxi, Sichuan, Hunan, Hainan, Guangxi, Macau; S. Japan
Liomyrmex	< 20	–	–	–	no China records
Lophomyrmex	21	–	–	–	Taiwan, Yunnan
Lordomyrma	37	–	–	–	no China records; central Japan
Mayriella	25	300	650	–	Hong Kong, Guangxi

Meranoplus	22	–	460	700	Hong Kong, Taiwan, Hainan, Guangdong, Yunnan, Guangxi
Metapone	23	–	–	–	Taiwan
Myopias	21	–	–	–	Taiwan, Yunnan
Myopopone	21	–	–	–	no China records; N. Vietnam
Myrmicaria	25	900	480	–	Yunnan, Guangdong, Guangxi
Myrmoteras	23	1020	150	1000	Yunnan, Hainan, Guangxi
Mystrium	21	–	–	880	Yunnan, Hainan; N. Vietnam
Ochetellus	37	–	530	–	Macau, Fujian, Taiwan, Shandong, Hunan, Shanghai, Jiangsu, Jiangxi, Zhejiang, Anhui, Guangxi, Yunnan, Hainan, Hong Kong; Korea
Odontomachus	40	1550	1300	1060	Taiwan, Hong Kong, Beijing, Fujian, Hainan, Guangdong, Zhejiang, Hunan, Sichuan, Shanghai, Hubei, Yunnan, Guangxi, Guizhou
Odontoponera	29	1030	560	860	Fujian, Hong Kong, Hainan, Taiwan, Guangdong, Guangxi, Yunnan, Zhejiang
Oecophylla	24	280	280	700	Guangdong, Hong Kong, Hainan, Yunnan, Guangxi
Pachycondyla	40	1810	1900	1740	Taiwan, Hong Kong, Hainan, Beijing, Fujian, Macau, Shanghai, Guangdong, Guizhou, Yunnan, Guangxi, Anhui, Zhejiang, Hubei, Jiangxi, Sichuan, Hunan, Xizang
Paratopula	23	–	–	–	Taiwan
Pheidologeton	36	280	1100	1030	Taiwan, Guangdong, Hong Kong, Macau, Fujian, Hainan, Guangxi, Zhejiang, Jiangxi, Shandong, Hunan
Philidris	21	–	–	340	Guangxi, Yunnan, Hainan
Platythyrea	21	–	–	–	Yunnan
Polyrhachis	38	1490	1200	1270	Hong Kong, Guangdong, Hainan, Fujian, Taiwan, Korea, Guangxi, Gansu, Jiangsu, Zhejiang, Anhui, Hubei, Sichuan, Hunan, Guizhou, Yunnan, Shanghai; north-central Japan
Prenolepis	34	2000	1900	1170	Hong Kong, Guangdong, Zhejiang, Anhui, Sichuan, Hunan, Jiangxi, Yunnan, Hubei, Sichuan, Guizhou, Guangxi, Hainan; southern Japan
Prionopelta	23	–	–	–	Taiwan
Probolomyrmex	27	–	270	360	Taiwan, Yunnan, Hainan, Hong Kong; south Japan
Proceratium	38	–	1100	–	Taiwan, Hunan, Guangdong, Zhejiang, Yunnan; Korea; north-central Japan
Protanilla	32	–	–	–	Yunnan; southern Japan
Pseudolasius	31	1390	1120	640	Hong Kong, Taiwan, Sichuan, Fujian, Hunan, Zhejiang, Hubei, Guizhou, Guangdong, Guangxi, Yunnan, Guangxi, Hainan
Pyramica	38	1110	1900	1360	Taiwan, Hong Kong, Guangdong, Guangxi, Zhejiang, Taiwan, Hainan; Korea; north-central Japan
Recurvidris	32	–	560	930	Fujian, Anhui, Hunan, Yunnan, Taiwan, Hong Kong, Hainan, Guangxi, Guangdong
Rhopalomastix	24	–	220	–	Hong Kong, Yunnan, Guangxi; south Japan
Rhoptromyrmex	32	1240	700	920	Taiwan, Hong Kong, Anhui, Hunan, Guangdong, Sichuan, Yunnan, Hainan, Guangxi
Rotastruma	28	–	400	–	Guangdong, Hong Kong, Hunan
Simopone	23	–	–	–	Taiwan
Solenopsis	40	1030	530	200	Taiwan, Beijing, Hong Kong, Macau, Fujian, Jiangsu, Hainan, Guangdong, Shandong, Jiangxi, Anhui, Guangxi, Zhejiang
Sphinctomyrmex	< 20	–	–	–	no China records
Tapinoma	40	960	860	1010	Hainan, Fujian, Beijing, Hong Kong, Guangdong, Macau, Hunan, Shandong, Anhui, Sichuan, Zhejiang, Guangxi, Yunnan, Taiwan, Hubei
Tetraponera	29	1080	980	900	Taiwan, Hong Kong, Hainan, Guangdong, Yunnan, Sichuan, Fujian, Jiangxi, Guangxi
Vombisidris	28	1320	–	–	Guangxi, Hunan

Tab. 2: The recorded southern latitudinal limits in the southeastern Palaearctic, and lower altitudinal limits in South China, of Palaearctic ant genera. From the author's field surveys, with first records from each province or administrative region. Digital supplementary material at the journal's web pages provides full references for Table 2.

Genus	Lowest latitude (°N)	Lowest altitude (m) in South China		China provinces and regions recorded (first record), and other records relevant to latitudinal reach
		mainland, 20 - 25° N, 105 - 106° E	mainland, 20 - 25° N, 107 - 114° E	
Cataglyphis	36	–	–	Shandong, Beijing, Liaoning, Xinjiang, Qinghai, Shanxi, Hebei
Formica	24	1580	–	Taiwan, Beijing, Gansu, Inner Mongolia, Shanxi, Sichuan, Fujian, Xizang, Heilongjiang, Shaanxi, Qinghai, Hubei, Xinjiang, Hebei, Jilin, Liaoning, Shandong, Anhui, Hunan, Yunnan, Guangdong, Zhejiang, Henan, Guangxi
Lasius	22	1400	760	Beijing, Gansu, Inner Mongolia, Shanxi, Taiwan, Hunan, Jiangsu, Shandong, Sichuan, Zhejiang, Liaoning, Fujian, Heilongjiang, Jilin, Shaanxi, Henan, Anhui, Hubei, Guizhou, Yunnan, Xizang, Hebei, Xinjiang, Guangdong, Guangxi; N. Vietnam (Hoang Lien Son)
Leptothorax	31	–	–	Hubei; Korea
Manica	35	–	–	no China records; central Japan
Messor	26	–	–	Shanghai, Beijing, Jiangsu, Hebei, Inner Mongolia, Shanxi, Shandong, Zhejiang, Anhui, Fujian, Hunan, Hubei, Shaanxi
Myrmica	22	1310	760	Sichuan, Yunnan?, Taiwan, Gansu, Jiangsu, Hunan, Hubei, Zhejiang, Anhui, Jilin, Heilongjiang, Shanxi, Beijing, Liaoning, Inner Mongolia, Hebei, Guangdong, Guangxi, Yunnan, Guangxi
Polyergus	33	–	–	Beijing, Gansu, Korea; southern Japan
Proformica	36	–	–	Sichuan, Beijing, Shandong, Hebei, Liaoning, Inner Mongolia
Strongylognathus	35	–	–	Beijing, Shaanxi; Korea
Temnothorax	23	–	320	Taiwan, Beijing, Fujian, Guangdong, Liaoning, Inner Mongolia, Anhui, Zhejiang, Hubei, Sichuan, Guangxi, Yunnan, Hunan

Tab. 3: Temperature zones in China (from ANON. 2002), with number of Oriental and Palaearctic ant genera in each.

Mean minimum temperature (January)	Number of Oriental genera	Number of Palaearctic genera
>10 °C	51	0
7.5 to 10 °C	46	0
5 to 7.5 °C	34	4
2.5 to 5 °C	32	5
0 to 2.5 °C	23	5
-2.5 to 0 °C	17	6
-5 to -2.5 °C	10	6
-10 to -5 °C	9	10
-15 to -10 °C	4	10
below -15 °C	0	10

I have recorded it in mainland South China, both west and east of 107° E. The median southern reach is 31° N, where winter temperature is just below 0 °C.

Table 3 summarises the number of Oriental and Palaearctic genera recorded within the winter-temperature bands in China.

The number of Oriental genera is higher than the number of Palaearctic genera (Fig. 2) but drops steadily moving northward. At around 37 - 38° N, where the winter

Tab. 4: Simple Matching Coefficient similarity matrix for ant genus composition among different latitudinal bands of provinces in China, based on Oriental and Palaearctic ant genera.

	36 - 40° N	31 - 35° N	26 - 30° N	21 - 25° N
31 - 35° N	84			
26 - 30° N	64	81		
21 - 25° N	29	44	64	
16 - 20° N	18	34	53	90

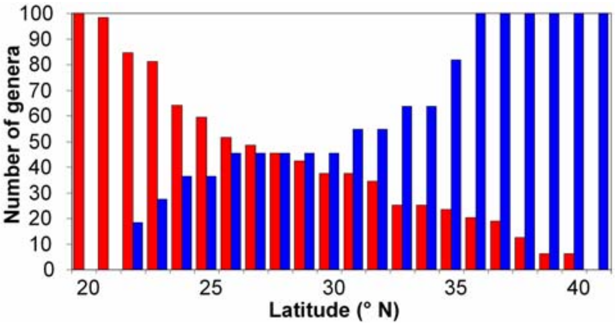

Fig. 3: Chart showing the percentage of East Asian Palaearctic (blue) and Oriental (red) genera occurring at different latitudes in eastern China.

Tab. 5: Simple Matching Coefficient similarity matrix for ant genus composition among different winter temperature bands in China, based on Oriental and Palaearctic ant genera.

	Below -15 °C	-15 to -10 °C	-10 to -5 °C	-5 to -2.5 °C	-2.5 to 0 °C	0 to 2.5 °C	2.5 to 5 °C	5 to 7.5 °C	7.5 to 10 °C
-15 to -10 °C	93								
-10 to -5 °C	85	92							
-5 to -2.5 °C	77	84	92						
-2.5 to 0 °C	66	72	80	88					
0 to 2.5 °C	54	61	69	77	89				
2.5 to 5 °C	39	46	54	62	74	85			
5 to 7.5 °C	34	41	49	57	69	80	95		
7.5 to 10 °C	10	16	25	33	45	56	70	75	
Over 10 °C	0	6.6	15	23	34	46	61	66	90

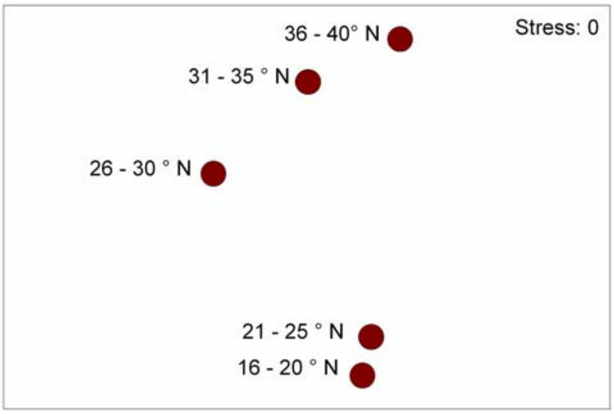

Fig. 4: Multidimensional scaling plot for composition of Palaearctic and Oriental genera in different latitudinal bands in East Asia. The stress value of 0 indicates excellent representation in two dimensions.

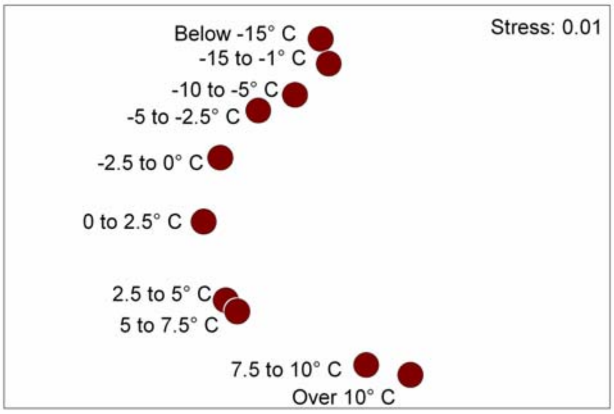

Fig. 5: Multidimensional scaling plot for composition of Palaearctic and Oriental genera in different winter-temperature bands in East Asia. The stress value of 0.01 indicates excellent representation in two dimensions.

temperature is about -10 °C, the number of Palaearctic genera exceeds the number of Oriental genera.

The proportion of Oriental genera present also drops steadily moving northward, while the proportion of Palaearctic genera drops moving southward (Fig. 3). The point at which the proportion of Oriental genera present exceeds the proportion of Palaearctic genera present is around 28° N, where the winter temperature is around 1 to 2 °C.

Table 4 shows the Simple Matching Coefficient similarity matrix between the genus compositions in each 5° latitudinal band; Table 5 shows the equivalent matrix for winter-temperature bands. All comparisons are dominated by the more numerous Oriental genera. Among adjacent latitudinal bands, the lowest similarity (64 %) is between 26 - 30° N and 21 - 25° N. Among adjacent temperature bands, the lowest similarity (75 %) is between 5 to 7.5 °C and 7.5 to 10 °C.

MDS of ant genus composition by latitudinal bands (Fig. 4) suggests a major division between 26 - 30° N and 21 - 25° N, and a second division between 26 - 30° N and 31 - 35° N. MDS by winter-temperature bands (Fig. 5) does not suggest any clear-cut division between two bands, but relatively high separation between 5 to 7.5 °C and 7.5 to 10 °C, and between 0 to 2.5 °C and 2.5 to 5 °C.

Tab. 6: Palaearctic-Oriental transition points by the various approaches considered.

Transition point	**Latitude (° N)**	**Winter temperature (°C)**
Extreme northern reach of Oriental genera	40 (by definition)	-10
Median northern reach of Oriental genera	25	3
Extreme southern reach of Palaearctic genera	22	7.5
Median southern reach of Palaearctic genera	31	0
Change in which component has the higher genus richness	37 - 38	-10
Change in which component has the higher proportion of respective East Asian genera	28	1 to 2
Lowest similarity between adjacent bands	21 - 25 to 26 - 30	7.5
Greatest separation in MDS plot	21 - 25 to 26 - 30	unclear
Greatest separation in cluster analysis	21 - 25 to 26 - 30	7.5

Tab. 7: Revised biogeographical affiliations of ant genera in East Asia.

Northern limit: / Southern limit:	N. Palaearctic (> 40° N)	S. Palaearctic (40° to 28° N)	N. Oriental (28° to 20° N)	S. Oriental (< 20° N)
N. Palaearctic (> 40° N)	*Alaucopone, Alloformica, Formicoxenus, Harpagoxenus, Rossomyrmex*			
S. Palaearctic (40° to 28° N)	*Cataglyphis, Leptothorax, Manica, Polyergus, Proformica, Strongylognathus*	none		
N. Oriental (28° to 20° N)	*Formica, Lasius, Messor, Myrmica, Temnothorax*	*Dacatria, Linepithema, Liometopum, Perissomyrmex*	*Bannapone* and unnamed new formicine genus (K.F.B.G. 2003, EGUCHI & al. 2004)	
S. Oriental (< 20° N)	*Amblyopone, Aphaenogaster, Bothriomyrmex, Cardiocondyla, Chalepoxenus, Crematogaster, Cryptopone, Dolichoderus, Hypoponera, Lepisiota, Monomorium, Myrmecina, Oligomyrmex, Paratrechina, Pheidole, Plagiolepis, Ponera, Pristomyrmex, Stenamma, Strumigenys, Technomyrmex, Tetramorium, Vollenhovia*	*Acropyga, Aenictus, Anochetus, Anomalomyrma, Cerapachys, Discothyrea, Gnamptogenys, Iridomyrmex, Leptanilla, Leptogenys, Lordomyrma, Ochetellus, Odontomachus, Odontoponera, Pachycondyla, Pheidologeton, Polyrhachis, Prenolepis, Proceratium, Protanilla, Pseudolasius, Pyramica, Recurvidris, Rhoptromyrmex, Solenopsis, Tapinoma, Tetraponera*	*Acanthomyrmex, Anillomyrma, Anoplolepis, Calyptomyrmex, Carebara, Cataulacus, Centromyrmex, Cladomyrma, Diacamma, Dilobocondyla, Dorylus, Echinopla, Emeryopone, Eurhopalothrix, Gesomyrmex, Harpegnathos, Kartidris, Lasiomyrma, Liomyrmex, Lophomyrmex, Mayriella, Meranoplus, Metapone, Myopias, Myopopone, Myrmicaria, Myrmoteras, Mystrium, Oecophylla, Paratopula, Philidris, Platythyrea, Prionopelta, Probolomyrmex, Rhopalomastix, Rotastruma, Simopone, Sphinctomyrmex, Vombisidris*	*Euprenolepis, Proatta*

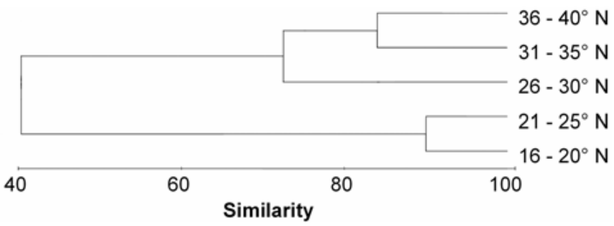

Fig. 6: Cluster dendrogram for composition of Palaearctic and Oriental genera in different latitudinal bands in East Asia.

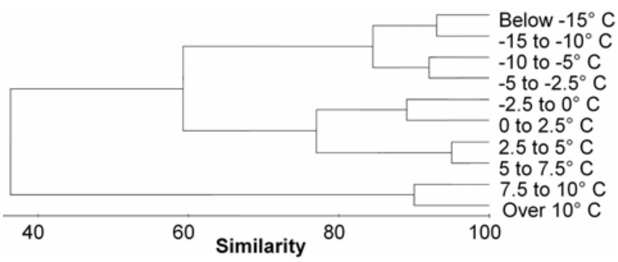

Fig. 7: Cluster dendrogram for composition of Palaearctic and Oriental genera in different winter-temperature bands in East Asia.

Table 6 summarises the various transition points suggested by these different approaches. Of the approaches used, most are influenced by the higher richness in Oriental than Palaearctic genera. The exception is the point, moving northward, at which the proportion of East Asian Oriental genera present is exceeded by the proportion of East Asian Palaeactic genera present (Fig. 2): about 28° N. This also falls between the median northern reach of Oriental genera (25° N) and the median southern reach of Palaearctic genera (31° N). It corresponds with the point where the January mean minimum temperature is around 1 to 2 °C (Fig. 8).

Based on this map a simplified classification of East Asian genera is given in Table 7. By this classification, of the 113 genera 11 (10 %) are strictly Palaearctic, 43 (38 %) are strictly Oriental, and the remaining 59 genera (52 %) have ranges spanning the Palaearctic and Oriental realms.

Discussion

The present findings can serve only as a tentative basis for drawing the Palaearctic-Oriental boundary for ants, until species-level identification is further advanced; this may not come, however, until the impacts of anthropogenic climate change are felt on ant distributions, and so the present effort seems justified. As suggested by existing biogeographical systems, there is no distinct boundary between the Palaearctic and Oriental ant fauna in China, but a broad transitional zone, with some 18 degrees between the northern limit of the Oriental fauna and the southern limit of the Palaearctic. But the approach favoured here, which gives equal weight to Oriental and Palaearctic taxa, suggests the biological centre of the boundary zone is around 28° N, corresponding to the provinces of northern Guizhou, northern Hunan, northern Jiangxi and Zhejiang. This does not closely match any of the established biogeo-

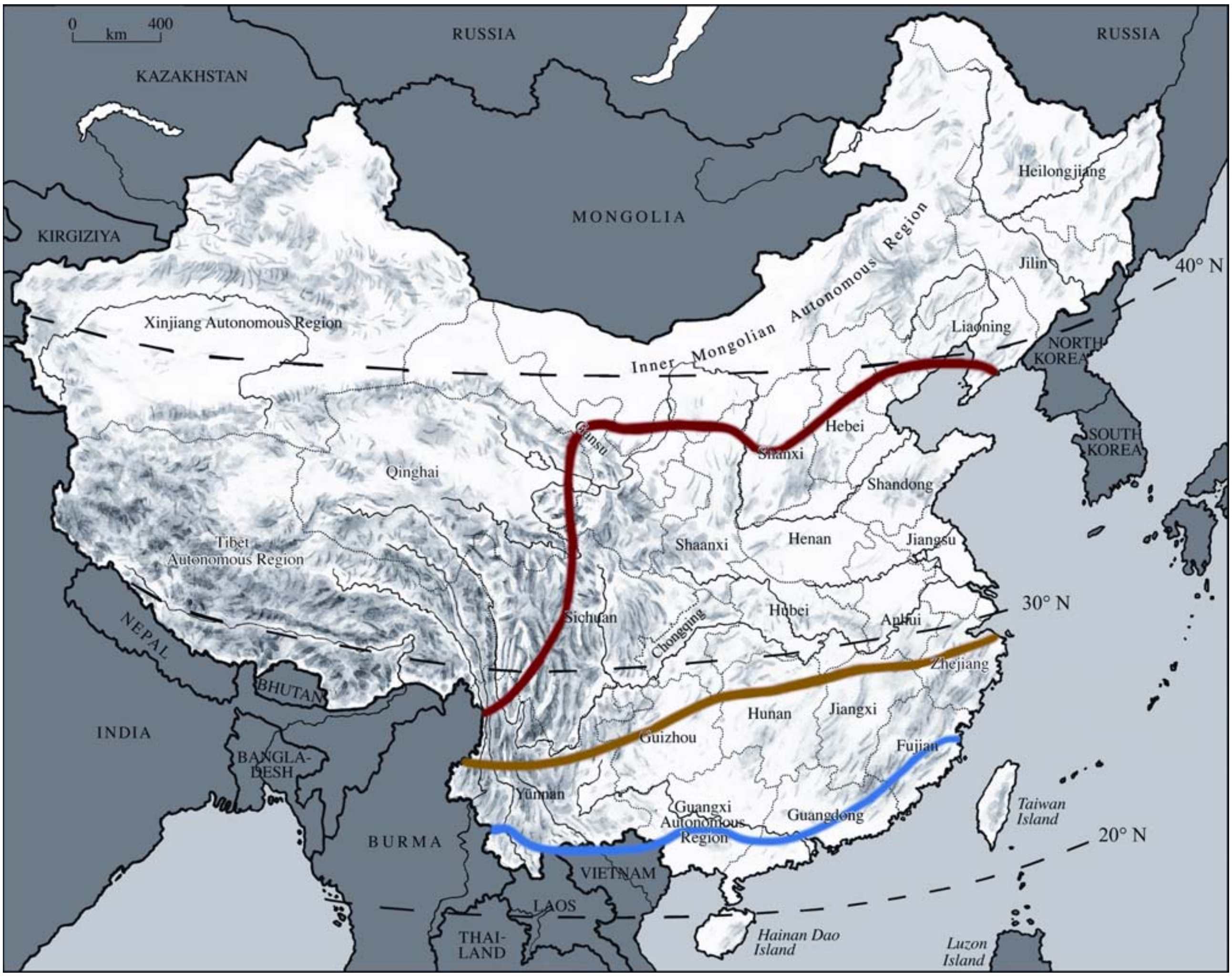

Fig. 8: Map showing the inferred Palaearctic-Oriental boundary (brown) for ants in China, based on the point at which the proportion of East Asia's Palaearctic genera exceeds the proportion of East Asia's Oriental genera. The upper red line approximates the extreme northern limit of Oriental genera, the lower blue line the extreme southern limit of Palaearctic genera. (Original map: © 1995 Natural History Museum Vienna).

graphical maps, but is similar to the northern boundary of the Mid-subtropical Climatic Zone (W. ZHANG 1998). Wherever the winter temperature drops below around 3 °C, most Oriental genera cannot survive, whereas most Palaearctic genera are absent in areas warmer than 0 °C in winter. On this basis the Sichuan basin in southeast Sichuan Province might also be expected to have a predominantly Oriental fauna, despite being further north. More altitude-referenced information from central China would be instructive.

A drawback of all the approaches is that they require setting an a priori, somewhat arbitrary distinction between realm-associated and latitudinally wide-ranging taxa. This is not problematic at the southern limit. At the northern limit four genera (*Odontomachus*, *Pachycondyla*, *Solenopsis*, and *Tapinoma*) are at their recorded limit at 40° N and might reasonably be omitted from the Oriental-associated list; if so the proportion of Oriental taxa exceeds that of Palaearctic genera at 27° N rather than 28° N. Conversely, the inclusion of certain genera which qualify only marginally as latitude-generalists (*Bothriomyrmex*, *Cryptopone*, *Lepisiota*, *Oligomyrmex*, *Paratrechina*, *Pristomyrmex*, *Strumigenys*, *Technomyrmex*, and *Vollenhovia*) in the Oriental fauna would change the transition to 30° N. Thus there would be some scope for interpretation even with improved knowledge of taxonomy and distribution.

The main mechanism for limiting distribution is uncertain. Temperature is important in controlling ant worker activity; even in tropical Hong Kong (22° N), where Palaearctic ant genera are absent, the cool season imposes an inactive period on ants, especially tropical taxa which are confined to lower elevations (FELLOWES 1996). In China there is a drop in temperature of approximately 1 °C for every 1° in latitude (from ANON. 2002) and for every 170 m in altitude (from DUDGEON & CORLETT 2004). The number of months at which the temperature is above a threshold activity level (about 15 - 21 °C in Hong Kong: FELLOWES 1996) may be at least as important as the lowest temperature. Besides dictating genus distributions, such temperature influences partially underlie the latitudinal gradient in species richness (DARLINGTON 1957, KUSNEZOV 1963, JEANNE 1979, TERAYAMA 1992). In East Asia the respective latitudinal bands (> 40° N, 36 - 40° N, 31 - 35°

N, 26 - 30° N, 21 - 25° N, 16 - 20° N, < 20° N) have 38, 51, 60, 65, 97, 90 and 92 recorded ant genera, the peak richness being at 21 - 25° N.

Whether Palaearctic genera are limited by physiological factors or others, such as competition, is not known. Where they are confined to a narrow altitudinal range, as in montane parts of southwest China, they must be considered at risk from projected global warming.

While temperature limits most genera, it is also possible that some of the Oriental genera are quite recent arrivals, or weak dispersers, in southern China. This might explain the apparent absence of some genera (*Anillomyrma*, *Carebara*, *Dilobocondyla*, *Dorylus*, *Kartidris*, *Mayriella*, and *Myrmicaria*) on Taiwan. The apparent absence of *Metapone*, and *Prionopelta* on mainland China and Indochina is more surprising, and raises the possibility of colonisation via the Philippines, but they may have been overlooked on the mainland.

Acknowledgements

The author's field data was collected largely during rapid biodiversity assessments funded by Kadoorie Farm & Botanic Garden, with permission and assistance from the Forestry Departments of Guangxi, Guangdong and Hainan. Most Hong Kong records were funded through a postgraduate studentship at The University of Hong Kong, and by the Biodiversity Survey of the Hong Kong Government. My thanks to David Dudgeon, Tong Xiaoli, Wang Min, Zhou Shanyi, Richard Corlett and especially Huang Jianhua for various contributions. Thanks also to Xu Zhenghui and one anonymous referee for their valuable inputs.

Zusammenfassung

Um die Grenze zwischen Paläarktis und Orientalis für Ameisen (Formicidae) in China zu bestimmen, wurden Verbreitungsangaben zusammengetragen. Von 67 orientalischen Gattungen in Ostasien kommen 34 (51 %) nicht weiter nördlich als 25° N vor, was somit die durchschnittliche Grenze für orientalische Ameisen ist. Von 11 paläarktischen Gattungen reichen sechs (55 %) nicht weiter in den Süden als 31° N, der durchschnittlichen Grenze für diese Taxa, und keine weiter südlich als 22° N. Die Zahl der orientalischen Gattungen überschreitet jene der paläarktischen Gattungen südlich von etwa 37° N. Die Verbreitungsangaben werden in Abschnitte von jeweils 5° geographischer Breite, sowie nach Jänner-Minimum-Temperaturen zusammengefasst. Diese Abschnitte werden mittels Simple Matching Coefficient of Similarity, Non-Metric Multidimensional Scaling und Cluster-Analyse verglichen. In all diesen Ansätzen resultiert die stärkste Grenze bei etwa 25 bis 26° N, ein Ergebnis, das allerdings überproportional stark von orientalischen Taxa beeinflusst wird. Der Anteil der ostasiatisch-paläarktischen Gattungen übersteigt den Anteil der ostasiatisch-orientalischen Gattungen bei etwa 28° N, wo die Wintertemperatur ungefähr 1 bis 2° C beträgt. Dieser von der Zahl der vorkommenden Gattungen beider Faunenzonen unabhängige Ansatz legt eine paläarktisch-orientalische Grenze nahe der nördlichen Grenze der innertropischen Klimazone nahe. Gemäß dieser Grenze sind etwa 10 % der ostasiatischen Gattungen auf die Paläarktis beschränkt, 38 % auf die Orientalis und 52 % kommen in beiden vor. Die Temperaturtoleranz ist wahrscheinlich ein besonders wichtiger limitierender Faktor für die Orientalische Fauna, und daher hat auch die Höhenlage einen bedeutenden Einfluss. In Zentral-China sind weitere Untersuchungen nötig, welche die Höhenlage einbeziehen.

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