Chapter 4

Phytogeography of Northeast Asia

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Abstract: Northeast Asia as defined in this study includes the Russian Far East, Northeast China, the northern part of the Korean Peninsula, and Hokkaido Island (Japan). We determined the species richness of Northeast Asia at various spatial scales, analyzed the floristic relationships among geographic regions within Northeast Asia, and compared the flora of Northeast Asia with surrounding floras. The flora of Northeast Asia consists of 971 genera and 4953 species of native vascular plants. Based on their worldwide distributions, the 971 genera were grouped into fourteen phytogeographic elements. Over 900 species of vascular plants are endemic to Northeast Asia. Northeast Asia shares 39% of its species with eastern Siberia-Mongolia, 24% with Europe, 16.2% with western North America, and 12.4% with eastern North America. Species richness and floristic relationships among different regions within Northeast Asia were discussed. The northernmost (Arctic) region shares 64% of its genera and 9% of its species with the southernmost (warm temperate) region. The geographic setting, climate, vegetation, and endemism of each of the eighteen regions of Northeast Asia were described and characterized. The geographic distributions of the 53 most important tree species in Northeast Asia were mapped.

Key words: affinity, biogeography, China, floristics, Japan, Korea, Russia, similarity, species richness

1. INTRODUCTION

Northeast Asia, as delineated in Fig. 4.1, includes the Russian Far East, Northeast China, the northern Korean Peninsula, and the island of Hokkaido (Japan). This area encompasses about 4,554,000 km^2, from 73° to near 37°N latitude and from 115°E to 169°W longitude. According to Takhtajan's (1986) floristic regionalization of the world, Northeast Asia consists of seven floristic provinces: the Arctic, Northeastern Siberian, Okhotsk-Kamchatka,

Manchurian, North China, Sakhalin-Hokkaido, and Japanese-Korean. The first three of these provinces belong to the Circumboreal Region and the remaining four to the East-Asian Region. In this chapter, we consider the species richness of Northeast Asia at various geographic scales. Floristic relationships within Northeast Asia are analyzed and compared floristically with the rest of the world.

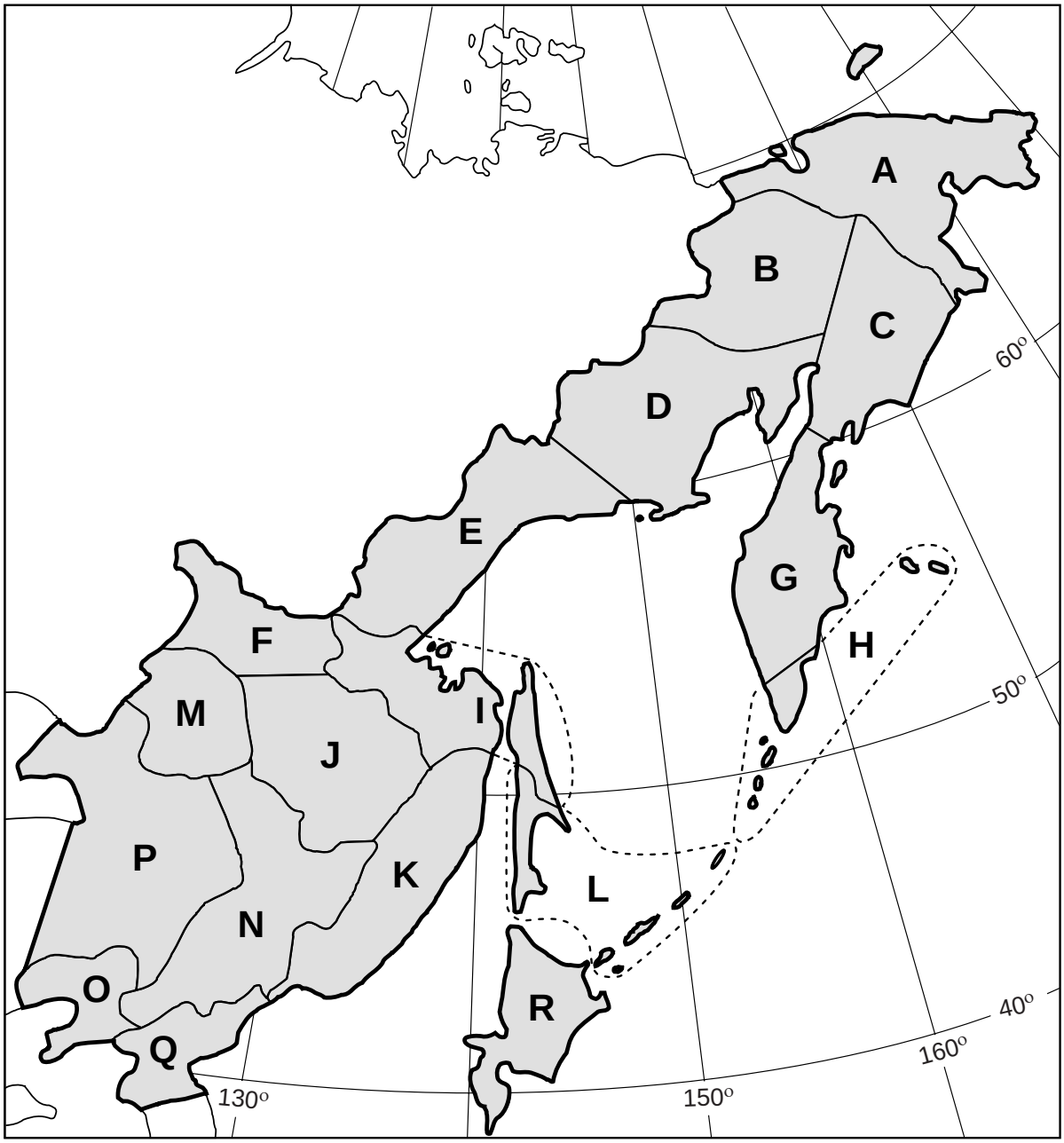

Figure 4.1. Northeast Asia as defined in this study, with its division into 18 regions. Full names for the 18 regions are given in Table 4.1.

2. MATERIALS AND METHODS

2.1 Study area

Northeast Asia is divided into 18 geographic regions, as delineated in Fig. 4.1. These regions are grouped into three zones latitudinally: northern part (regions A, B, C, and D), central part (regions E, F, G, H, I, J, K, L, and M), and southern part (regions N, O, P, Q, and R).

2.2 Floristic data sources

The major sources used in compiling the floristic data-base for Northeast Asia include the following: "Plantae Vasculares Orientis Extremi Sovietici" (Charkevicz 1985–1996, 8 vols.), "Flora Sibiriae" (Krasnoborov *et al.* 1988–1997, 14 vols.), "Clavis Plantarum Chinae Boreali-Orientalis" (Fu 1995), "Illustrated Flora of Korea" (Lee 1980), "Dictionary of Plant Names" (Ri & Hoang 1984), "Lineamenta Florae Koreae" (Lee 1996), "Flora of Japan" (Iwatsuki *et al.* 1993–1999), "New Flora of Japan" (Spermatophyta, Ohwi & Kitagawa 1992; Pteridophyta, Nakaike 1992), and the "Checklist of Higher Plants in Hokkaido" (Ito 1985–1994, 4 vols.). "The Flora Republicae Popularis Sinicae" (FRPS, Anonymous 1959–1998, 80 vols.), "Flora of China" (English and revised edition of FRPS, Wu & Raven 1994–2000), "Vascular Plants of Russia and Adjacent States" (Czerepanov 1995), and many recently published journal articles pertinent to the flora of Northeast Asia were used as well.

Species ranges outside Northeast Asia were obtained from various sources. These included "Vascular Plants of Russia and Adjacent States" (Czerepanov 1995), "Flora Europaea" (Tutin *et al.* 1964–1980), "Flora Sibiriae" (Krasnoborov *et al.* 1988–1997), "Key to the Vascular Plants of Mongolia" (Grubov 1982), "Illustrated Flora of Korea" (Lee 1980), "Flora of Japan" (Iwatsuki 1993–1999), "New Flora of Japan" (Ohwi & Kitagawa 1992; Nakaike 1992), "Flora Republicae Popularis Sinicae" (Anonymous 1959–1998), "Flora of China" (Wu & Raven 1994–2000) for the Eurasian flora; and "A Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland" (Kartesz 1994) and "BONAP's 1999 Phytogeography Data" (Biota of North America Program 1999) for the North American flora. Worldwide generic distributions were mostly based on Wielgorskaya (1995) and Mabberley (1997).

2.3 Standardization of botanical nomenclature

There are noticeable differences among the botanical nomenclature from floristic references for China, Russia, Korea, and Japan. In general, Russian botanists tended to use a narrower species concept than those in other East Asian countries. Many taxa considered as subspecies or varieties outside Russia are recognized as different species in the Russian literature. Further, many taxa recognized as different species by Russian botanists are considered as the same species by botanists in other Asian countries and North America. For example, *Erophila praecox*, *E. spathulata*, *E. verna*, *Poa alpigena*, *P. angustifolia*, *P. pratensis*, *Trisetum alaskanum*, *T. molle*, and *T. spicatum* were recognized as nine different species in Czerepanov (1995) but only three species, *Draba verna*, *Poa pratensis*, and *Trisetum spicatum*, by Kartesz (1994). The species concept for vascular plants is more or less comparable in China and North America (Qian & Ricklefs 1999). In general, we followed a broad species concept in standardizing the botanical nomenclature for the taxa in Russia, Korea, and Japan. "The Flora Europaea" (Tutin *et al.* 1964–1980), whose botanical nomenclature practice is generally comparable to that of Kartesz, was used fre-

quently in standardizing the botanical nomenclature of Northeast Asia.

Nomenclatural standardization at the genus level followed "Phytogeographic Checklist of Vascular Plant Genera of the Northern Hemisphere" (VPGNH version 2000; H. Qian, unpublished materials). In VPGNH, genus names of spermatophytes were generally accepted if adopted by all of Brummitt (1992), Greuter *et al.* (1993), Mabberley (1997), and Wielgorskaya (1995); or, for pteridophytes (omitted in Wielgorskaya), if the first three of these plus Kramer & Green (1990) accepted the name. Grouping of genera into families followed Brummitt (1992) for pteridophytes, Wielgorskaya (1995) for gymnosperms, and Takhtajan (1997) for angiosperms.

2.4 Data analysis

Floristic relationships between different regions of Northeast Asia, at both the genus and species level, were assessed by means of similarity indices and distances in multivariate ordinations. Pairwise comparisons used the Sørensen (1948) similarity index,

$$I_{\text{Sør}} = \frac{2a}{2a+b+c} \quad (1)$$

and the Simpson (1960) similarity index,

$$I_{\text{Sim}} = \frac{a}{a+b} \quad (2)$$

in which a is the number of taxa common to both regions, b is the number of taxa restricted to one region, and c is the number of taxa restricted to the other region ($b \le c$). When I_{Sim} is multiplied by 100, the resulting value represents the percent of taxa in the region with the lower number of taxa that are shared with the region with the higher number of taxa.

Non-metric multidimensional scaling (NMDS) was used to ordinate the regional floras in Northeast Asia, using the Sørensen coefficient as a measure of dissimilarity between floras. Three NMDS ordinations were conducted using PC-ORD (McCune & Mefford 1997), two at the genus level (one on genus presence/absence data and the other on species-richness data) and one at the species level (on species presence/absence data). To quantify floristic relationships among floras in a 3-D NMDS ordination space, distances (D) between two floras for each pair were calculated using the following formula:

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \quad (3)$$

where x_1 and x_2, y_1 and y_2, and z_1 and z_2 are the scores of the first, second, and third dimensions, respectively, of the NMDS for the pair of compared floras.

3. RESULTS AND DISCUSSION

3.1 Species diversity

The flora of Northeast Asia consists of 211 families, 971 genera and 4953 species of native vascular plants. Pteridophytes, gymnosperms, and angiosperms make up 5.7, 1.1, and 93.2% of the genera, respectively, and 4.4, 0.7, and 94.9% of the species. The total numbers of vascular plant species in the northern, central, and southern zones of Northeast Asia are 1220, 2578, and 4237, respectively.

There are 12 families in Northeast Asia that have more than 100 species each. These families are the Asteraceae (561 species in Northeast Asia), Poaceae (396), Cyperaceae (375), Ranunculaceae (233), Rosaceae (227), Fabaceae (219), Brassicaceae (155), Caryophyllaceae (139), Scrophulariaceae (131), Polygonaceae (131), Lamiaceae (131), and Apiaceae (106). Species of these families account for 56.6% of the total flora. The 10 largest genera in Northeast Asia are *Carex* (271 species), *Polygonum* (87), *Salix* (85), *Taraxacum* (83), *Artemisia* (76), *Saussurea* (70), *Oxytropis* (69), *Viola* (69), *Potentilla* (65), and *Saxifraga* (54). Species richness decreases markedly, as expected, from south to north

(Table 4.1). An area in the south can have 2–3 times as many species as a northern area of the same size.

Table 4.1. Number of genera and species of native vascular plants in each of the 18 regions recognized in Northeast Asia (see Fig. 4.1 for the delineation of each region).

Geographic region	Region code	No. of genera	No. of species
Chukotka	A	214	758
Anuj	B	184	554
Koriakia	C	233	747
Kolyma–Northern Okhotsk	D	299	1016
Aldan–Southern Okhotsk	E	309	985
Upper Amur	F	361	1015
Kamchatka	G	312	891
Commander Islands–Northern Kuril Archipelago	H	308	899
Amgu–Northern Sakhalin	I	424	1219
Middle Amur	J	509	1442
Ussuri	K	610	1943
Southern Sakhalin–Southern Kuril Archipelago	L	474	1268
Daxingan-ling	M	425	1161
Xiaoxingan-ling–Changbai-shan	N	606	1872
Liaoning	O	620	1600
Eastern Neimonggu (eastern Inner Mongolia)	P	521	1474
North Korea	Q	636	1767
Hokkaido	R	641	1716

3.2 Rarity and endemism

3.2.1 Rarity

About 45% of the 4953 species known in Northeast Asia occur in only one or two of the 18 regions (Fig. 4.2); fewer than 1% occur in all 18 regions. Widely distributed species include *Agrostis clavata*, *Alopecurus aequalis*, *Barbarea orthoceras*, *Beckmannia syzigachne*, *Calamagrostis langsdorffii*, *Callitriche palustris*, *Caltha palustris*, *Chrysosplenium alternifolium*, *Cicuta virosa*, *Epilobium angustifolium*, *E. palustre*, *Equisetum arvense*, *E. palustre*, *Erigeron acris*, *Fallopia convolvulus*, *Juncus bufonius*, *Luzula multiflora*, *Moehringia lateriflora*, *Parnassia palustris*, *Poa pratensis*, *Pyrola rotundifolia*, *Rumex acetosa*, *Salix udensis*, *S. viminalis*, *Sanguisorba officinalis*, *Thalictrum minus*, and *Utricularia macrorhiza*. Some of these species may occur as different infra-specific forms in different regions.

3.2.2 Endemism

There is no endemic family in Northeast Asia and about seven genera of endemic vascular plants: *Astilboides*, *Astrocodon*, *Diplandrorchis*, *Magadania*, *Microbiota*, *Miyakea*, and *Pentactina*. A few other genera more or less restricted to Northeast Asia (e.g. *Borodinia*, *Gorodkovia*, and *Mukdenia*) do extend somewhat outside the area defined herein.

Over 900 species, approximately 18.4% of the total flora, are endemic to Northeast Asia (Table 4.2). Of these endemic species, 585 are restricted to the southern, more temperate part of Northeast Asia, 87 to the central part, and about 70 to the northern part. About 80% (750) of the endemic species, including trees such as *Abies sachalinensis*, *Celtis cordifolia*, *Larix olgensis*, *Picea koraiensis*, *Populus amurensis*, and *Thuja koraiensis*, are restricted to the southern and central parts of Northeast Asia. Approximately 60% of the endemic species belong to the following nine families: Asteraceae (172 species), Fabaceae (65), Ranunculaceae (62), Poaceae (61), Cyperaceae (56), Lamiaceae (37), Saxifragaceae (36), Rosaceae (32), and Scrophulariaceae (30).

Among the endemic species of Northeast Asia are *Antennaria pseudoarenicola*, *Arctanthemum integrifolium*, *Arenaria tschuktschorum*, *Astragalus ishigensis*, *Campanula tschuktschorum*, *Cardamine sphenophylla*, *Carex pseudodahurica*, *C. microchaeta*, *Castilleja variocolorata*, *Chrysosplenium arctomontanum*, *C. saxatile*, *Corispermum mayanense*, *C. ochotense*, *Delphinium kolymense*, *Draba majae*, *Gastrolychnis soczaviana*, *Hedysarum mackenzii*, *Helictotrichon krylovii*,

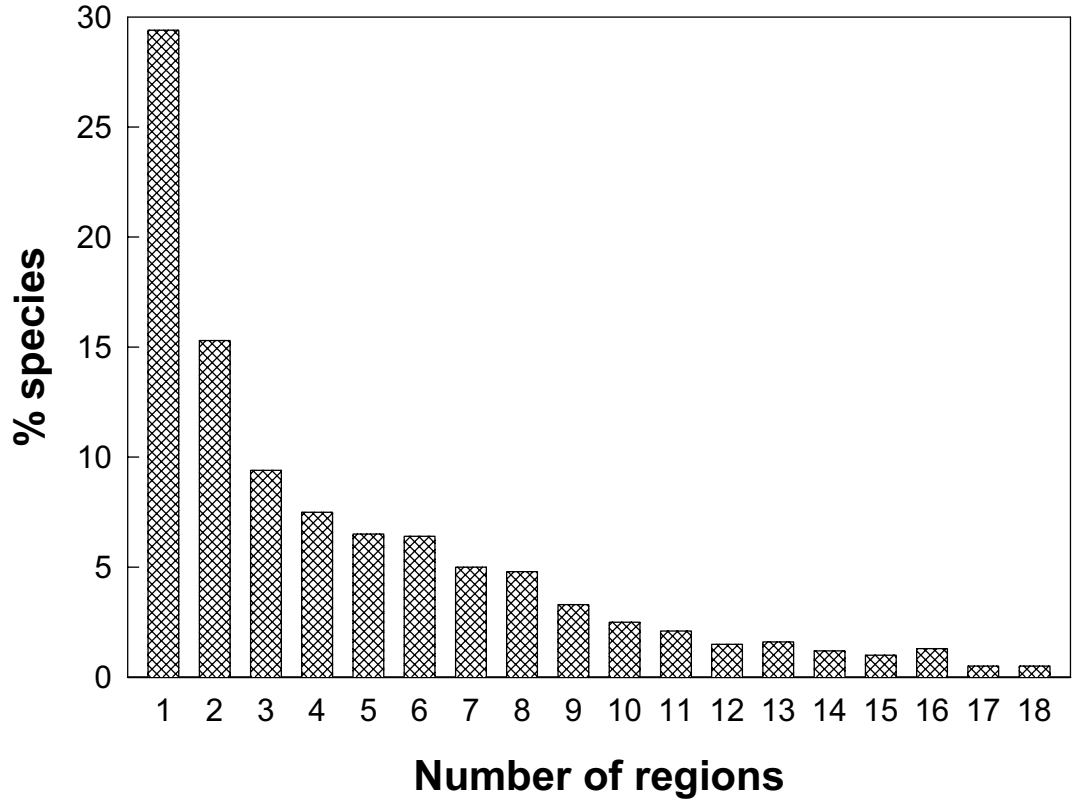

Figure 4.2. Frequency distribution of vascular plant species of Northeast Asia, in terms of the number of regions of Northeast Asia in which a species occurs.

Leontopodium stellatum, *Minuartia tricostata*, *Montia vassilievii*, *Oxytropis beringensis*, *O. kateninii*, *O. schmorgunoviae*, *O. susumanica*, *O. sverdrupii*, *O. uschakovii*, *O. wrangelii*, *Papaver anadyrense*, *P. anjuicum*, *P. atrovirens*, *P. chionophilum*, *P. gorodkovii*, *P. paucistaminum*, *P. multiradiatum*, *P. uschakovii*, *Pedicularis kolymensis*, *Phyllospadix juzepczukii*, *Poa arctostepporum*, *P. tzvelevii*, *Potentilla anadyrensis*, *P. beringensis*, *P. rupifraga*, *P. villosula*, *P. wrangelii*, *Ranunculus punctatus*, *Salix khokhriakovii*, *Saussurea tomentosella*, *Saxifraga arctolitoralis*, *Solidago compacta*, *Sparganium probatovae*, *Suaeda arctica*, *Taraxacum anadyrense*, *T. kolymense*, *T. korjakense*, *T. leucocarpum*, *Tephroseris schistosa*, *Trollius chartosepalus*, and *Veronica callitrichoides*.

3.3 Floristic relations of Northeast Asia to the world's flora at the genus level

The 971 vascular genera in Northeast Asia were grouped into 14 phytogeographical elements (see Table 4.3), according to their worldwide distributions and following the criteria of Wu (1980, 1991, Wu & Wang 1983), with the exception of the China's endemic genera, which were included in the eastern Asian element.

3.3.1 Cosmopolitan

Genera regarded as cosmopolitan occur

across all or nearly all continents of the earth. In general, they do not have special distribution centers, or occasionally have one or a few centers of high diversity but still occur worldwide. In the world, there are about 132 vascular genera in this category (Qian 1999), 119 of which are present in Northeast Asia. Some of these cosmopolitan genera have much of their species diversity centered in temperate regions but also have a noticeable distribution in high elevations of the tropics. These genera include *Anemone*, *Cardamine*, *Clematis*, *Convolvulus*, *Cuscuta*, *Eleocharis*, *Galium*, *Geranium*, *Hypericum*, *Juncus*, *Luzula*, *Plantago*, *Poa*, *Polygonum*, *Ranunculus*, *Rhamnus*, *Rubus*, and *Teucrium*.

Table 4.2. Number of species endemic to Northeast Asia (listed by family).

Family	No. of species
Adoxaceae	1
Alliaceae	2
Apiaceae	15
Aquifoliaceae	1
Araceae	1
Asteraceae	172
Balsaminaceae	2
Betulaceae	4
Boraginaceae	6
Brassicaceae	21
Campanulaceae	9
Caprifoliaceae	5
Caryophyllaceae	25
Celastraceae	2
Chenopodiaceae	9
Convallariaceae	2
Convolvulaceae	1
Cornaceae	1
Crassulaceae	12
Cupressaceae	2
Cyperaceae	56
Daphniphyllaceae	1
Droseraceae	1
Dryopteridaceae	2
Empetraceae	1
Ericaceae	10
Eriocaulaceae	9
Euphorbiaceae	4
Fabaceae	65
Fagaceae	3
Fumariaceae	7
Gentianaceae	7
Geraniaceae	4
Grossulariaceae	4
Hemerocallidaceae	3
Hippuridaceae	1
Hostaceae	1
Hydrangeaceae	1
Hypericaceae	4
Iridaceae	5
Juncaceae	9
Lamiaceae	37
Lemnaceae	1
Liliaceae	6
Linaceae	1
Lycopodiaceae	1
Lythraceae	1
Melanthiaceae	4
Najadaceae	2
Oleaceae	5
Onagraceae	1
Ophioglossaceae	2
Orchidaceae	8
Papaveraceae	11
Pinaceae	4
Plagiogyriaceae	1
Plantaginaceae	2
Plumbaginaceae	1
Poaceae	61
Polemoniaceae	4
Polygonaceae	23
Polypodiaceae	3
Portulacaceae	2
Primulaceae	10
Ranunculaceae	62
Rhamnaceae	3
Rosaceae	32
Rubiaceae	4
Rutaceae	1
Salicaceae	19
Sambucaceae	1
Saxifragaceae	36
Scrophulariaceae	30
Sparganiaceae	4
Spigeliaceae	1
Thymelaeaceae	1
Tiliaceae	1
Trapaceae	2
Trilliaceae	2
Ulmaceae	1
Urticaceae	3
Valerianaceae	4
Violaceae	19
Woodsiaceae	4
Zannichelliaceae	1
Zosteraceae	1

Table 4.3. Number of vascular plant genera in Northeast Asia according to phytogeographical element.

Phytogeographical element	No. of genera
Cosmopolitan	119
Pantropical	89
Amphi-Pacific Tropical	17
Paleotropical	32
Tropical Asia–Tropical Australia	12
Tropical Asia–Tropical Africa	10
Tropical Asia	12
Holarctic	295
Eastern Asia–North America	80
Temperate Eurasia	118
Temperate Asia	36
Mediterranean, western Asia to central Asia	20
Central Asia	13
Eastern Asia	118
Total	*971*

Many of the cosmopolitan genera inhabit either hydric or mesic sites. For example, *Apium*, *Brasenia*, *Callitriche*, *Ceratophyllum*, *Cladium*, *Hippuris*, *Hydrocotyle*, *Lemna*, *Limosella*, *Ludwigia*, *Myriophyllum*, *Najas*, *Nymphaea*, *Nymphoides*, *Phragmites*, *Potamogeton*, *Ruppia*, *Samolus*, *Scirpus*, *Spirodela*, *Typha*, *Utricularia*, *Wolffia*, and *Zannichellia* are aquatic or nearly aquatic plants, while *Anemone*, *Astragalus*, *Clematis*, *Galium*, *Geranium*, *Polygonum*, *Ranunculus*, *Rhamnus*, *Rubus*, *Senecio*, and *Solanum* are primarily mesophytes (although some of their members inhabit hydric or xeric sites as well).

3.3.2 Pantropical

Genera found in all the three sectors of the tropical zone (i.e. the Americas, Africa-Madagascar, and Asia-Australia) are considered to be pantropical genera, though some of these genera may extend into temperate regions. By this definition, 89 vascular genera of Northeast Asia are pantropical, including *Abutilon*, *Acalypha*, *Achyranthes*, *Aeschynomene*, *Andropogon*, *Arachniodes*, *Ardisia*, *Aristida*, *Aristolochia*, *Arthraxon*, *Azolla*, *Begonia*, *Boehmeria*, *Bothriochloa*, *Bulbostylis*, *Buxus*, *Calanthe*, *Callicarpa*, *Cassia*, *Celastrus*, *Chloris*, *Clerodendrum*, *Cocculus*, *Commelina*, *Coniogramme*, *Conyza*, *Crotalaria*, *Cynanchum*, *Cynodon*, *Dioscorea*, *Diplachne*, *Eclipta*, *Elatine*, *Eleusine*, *Eriocaulon*, *Eriochloa*, *Fimbristylis*, *Habenaria*, *Hibiscus*, *Impatiens*, *Imperata*, *Indigofera*, *Ipomoea*, *Isachne*, *Ischaemum*, *Kyllinga*, *Lacosteopsis*, *Laportea*, *Leersia*, *Lipocarpha*, *Loxogramme*, *Mecodium*, *Mollugo*, *Oplismenus*, *Ottelia*, *Pennisetum*, *Phaseolus*, *Phyllanthus*, *Pilea*, *Polypogon*, *Portulaca*, *Rhynchosia*, *Rotala*, *Sacciolepis*, *Salvinia*, *Schizachyrium*, *Scleria*, *Securinega*, *Setaria*, *Siegesbeckia*, *Smilax*, *Sporobolus*, *Styrax*, *Tetragonia*, *Tribulus*, *Tripogon*, *Vallisneria*, *Vandellia*, *Vitex*, *Wedelia*, and *Zanthoxylum*.

3.3.3 Amphi-Pacific tropical

This element is equivalent to the combination of the "Tropical Asia–Tropical America" areal type and "Tropical Asia–Tropical Australia–Tropical America" areal subtype in Wu (1991). Genera falling into this category have disjunct distributions in both the Americas and Asia–Australia but are absent from tropical Africa–Madagascar. Some such genera may occur sporadically on Pacific islands or may extend into temperate regions. Northeast Asia contains 17 such genera, 10 of which occur in both tropical Asia and tropical Australia, for example *Dennstaedtia*, *Desmodium*, *Haloragis*, *Lespedeza*, *Cudrania*, *Nelumbo*, and *Symplocos*. Seven Amphi-Pacific tropical genera (e.g. *Clethra* and *Meliosma*) do not occur in Australia.

3.3.4 Paleotropical

This element was termed "Old World Tropics" in Wu (1980, 1991) and many other publications (e.g. Qian 1989, Ying *et al.* 1991, Cao *et al.* 1995, Fu *et al.* 1995a, b, c). Genera falling into this category occur in the tropics of all three continents of the Old World: Asia, Australia, and Africa (including Madagascar). There are 32 genera in Northeast Asia belonging to this distribution type, including *Alangium*, *Asparagus*, *Blyxa*, *Caldesia*, *Capilli-*

pedium, *Cayratia*, *Cymbopogon*, *Elatostema*, *Epipogium*, *Euodia*, *Flueggea*, *Glycine*, *Grewia*, *Hydrilla*, *Limnophila*, *Monochoria*, *Murdannia*, *Plectranthus*, *Themeda*, *Tylophora*, *Viscum*, *Davallia*, *Gonocormus*, *Periploca*, *Pyrrosia*, and *Tragus*.

3.3.5 Tropical Asia–Tropical Australia

Genera included in this category are restricted to Asia and Australia and are mainly distributed in the tropical regions of the two continents. Twelve genera present in Northeast Asia can be placed in this category. Among them are *Boea*, *Cymbidium*, *Dimeria*, *Dysophylla*, *Gastrodia*, *Mitrasacme*, *Mazus*, *Leptopus*, *Pueraria*, and *Trichosanthes*.

3.3.6 Tropical Asia–Tropical Africa

Genera in this category are restricted to Asia and Africa, mainly in tropical regions of the two continents. In Northeast Asia 10 genera belong to this category, including *Girardinia*, *Microstegium*, *Miscanthus*, *Phacelurus*, and *Thladiantha*.

3.3.7 Tropical Asia

Genera in this category are mainly restricted to tropical Asia. Although some of these genera may extend northward to temperate regions, they do not reach Australia to the south, Africa to the west, or the New World across the Pacific. Twelve such genera in Northeast Asia, e.g. *Broussonetia*, *Chloranthus*, *Daphniphyllum*, *Duchesnea*, *Gynostemma*, and *Ixeris*, are included in this category.

3.3.8 Holarctic

This category has been frequently called "North Temperate" (e.g. Wu & Wang 1983, Wu 1991, Ying *et al.* 1991), Eurasian–North American (e.g. Thorne 1972), or Circumpolar sensu lato. Genera included in this category are widely distributed in all temperate (including boreal and arctic) regions of Europe, Asia, and North America, with some appearing at high elevations in tropical mountains or at southern latitudes. The world's flora contains 305 holarctic vascular plant genera (Qian 1999), the majority occurring widely in both the northern temperate and boreal zones. Many are also present in the arctic zone. About 97% (295) of the world's holarctic genera occur in Northeast Asia, which represent about 30% of the total vascular flora of Northeast Asia.

More than 50 holarctic genera are woody plants; these dominate much of the forest vegetation as well as non-forest vegetation (e.g. arctic and alpine tundra) in temperate areas of the Northern Hemisphere (Qian 1999). For example, coniferous tree genera include *Abies*, *Cupressus*, *Juniperus*, *Larix*, *Picea*, *Pinus*, and *Taxus*; broad-leaved tree genera include *Acer*, *Alnus*, *Amelanchier*, *Betula*, *Carpinus*, *Castanea*, *Cercis*, *Elaeagnus*, *Fagus*, *Fraxinus*, *Juglans*, *Malus*, *Morus*, *Ostrya*, *Populus*, *Prunus*, *Quercus*, *Salix*, *Sorbus*, *Tilia*, and *Ulmus*. Species of these genera dominate most of the forest communities in Northeast Asia. Genera involving mainly tall shrubs, mostly occurring in forests, include *Berberis*, *Cornus*, *Corylus*, *Cotinus*, *Crataegus*, *Lonicera*, *Philadelphus*, *Rhododendron*, *Rhus*, *Ribes*, *Rosa*, *Spiraea*, and *Viburnum*; those involving dwarf-shrub species, occurring mostly in arctic–alpine or boreal–subalpine areas, include *Arctostaphylos* (including *Arctous*), *Chamaedaphne*, *Dryas*, *Empetrum*, *Ledum*, *Loiseleuria*, and *Phyllodoce*. *Vitis*, a genus of woody vines, can be found in many forests in Northeast Asia, particularly in its southern part.

The holarctic area can be divided latitudinally into three zones: circum-temperate (sensu stricto), circum-boreal, and arctic circumpolar. According to Thorne (1972), there are 118 circum-temperate genera, most of which have a relatively continuous distribution across Eurasia and North America (e.g. *Betula*, *Cypripedium*, *Lilium*, *Populus*, *Quercus*, and *Veratrum*). In many of these genera,

however, one or more species also occur in the boreal or arctic zone (e.g. *Armeria*, *Chimaphila*, *Juniperus*, *Parnassia*, and *Pedicularis*) (Qian 1999). Genera occurring mainly in the circum-boreal zone include *Andromeda*, *Chamaedaphne* (*Cassandra*), *Comarum*, *Eriophorum*, *Linnaea*, and *Menyanthes*, although some (e.g. *Linnaea*) may frequently be found also in temperate forests. True circum-polar genera are few, *Dupontia* being probably the only genus more or less restricted to the circum-polar zone. There are about 30 vascular genera, however, that are major components of the circum-polar flora but also extend into alpine zones of boreal, temperate, and occasionally tropical regions (Qian 1999). Among these genera are *Arctagrostis*, *Arctanthemum*, *Arnica*, *Braya*, *Calla*, *Chamaedaphne*, *Diapensia*, *Dryas*, *Empetrum*, *Honckenya*, *Koenigia*, *Ledum*, *Loiseleuria*, *Oxyria*, *Parrya*, *Phippsia*, *Phyllodoce*, and *Scheuchzeria*.

3.3.9 Eastern Asian–North American

Genera included in this category have disjunct distributions in temperate to subtropical East Asia and North America. This group of genera has been much studied since the pioneering work of Asa Gray (1840, 1846), e.g. by Hu (1935, 1936), Li (1952, 1972), Hara (1952, 1956, 1972), Graham (1972), Boufford & Spongberg (1983), Wu & Wang (1983), Hong (1993), Wen (1999), Qian (1999), Qian & Ricklefs (2000), and Guo & Ricklefs (2000). According to Qian (1999), about 120 vascular genera show this type of disjunct distribution, 80 of which occur in Northeast Asia, many of them are present only in the southern part of the region. For example, *Magnolia* and *Lindera* are well known eastern Asian–eastern North American disjunct genera and have 54 and 97 species, respectively, in eastern Asia (particularly in warmer temperate and subtropical forests). Only three species of *Magnolia* and four of *Lindera* extend northward to the southern part of Northeast Asia. Some of the species also occur widely, however, in subtropical China (e.g. *Magnolia sieboldii* and *Lindera glauca*). Some of the 80 eastern Asian-North American disjunct genera that occur in Northeast Asia also occur widely across North America, from east to west, while others are restricted to either eastern or western North America. Genera occurring in both eastern and western North America include *Agastache*, *Amsonia*, *Dicentra*, *Disporum*, *Elliottia* (including *Cladothamnus* and *Tripetaleia*), *Enemion*, *Menziesia*, *Mitella*, *Smilacina*, *Thuja*, *Tiarella*, *Trautvetteria*, and *Trillium*. Genera restricted to eastern North America include *Adlumia*, *Camptosorus*, *Caulophyllum*, *Diphylleia*, *Hydrangea*, *Jeffersonia*, *Lindera*, *Magnolia*, *Menispermum*, *Mitchella*, *Onoclea*, *Penthorum*, *Phryma*, *Symplocarpus*, and *Zizania*. Genera restricted to western North America are fewer and include *Achlys*, *Glehnia*, *Lysichiton*, *Nephrophyllidium*, *Oplopanax*, *Phyllospadix*, *Podistera*, *Tilingia*, and *Wilhelmsia*. Most of these genera are restricted to Northeast Asia plus northwestern North America, which suggests that they were recently separated, probably due to climate warming after the Quaternary glaciations.

3.3.10 Temperate Eurasia

This category has also been called “Old World Temperate” (e.g. Wu 1980, 1991) and includes genera that occur widely across temperate Europe and Asia. Some may also extend into northernmost Africa, but they do not occur in the New World. In Northeast Asia 119 genera belong to this category, including *Adenophora*, *Adonis*, *Aegopodium*, *Agropyron*, *Agrostemma*, *Ajuga*, *Amethystea*, *Anthoxanthum*, *Anthriscus*, *Arctium*, *Avena*, *Berteroa*, *Blysmus*, *Buglossoides*, *Butomus*, *Callianthemum*, *Capsella*, *Carduus*, *Carpesium*, *Chelidonium*, *Cleistogenes*, *Coleanthus*, *Cortusa*, *Crypsis*, *Cucubalus*, *Dendranthema*, *Dianthus*, *Diarthron*, *Dictamnus*, *Dipsacus*, *Echinops*, *Elytrigia*, *Epimedium*, *Eranthis*, *Fagopyrum*, *Gagea*, *Galeopsis*, *Gastrolychnis*, *Gypsophila*, *Hemarthria*, *Hemerocallis*, *Her-*

minium, *Hylotelephium*, *Inula*, *Isatis*, *Isopyrum*, *Lagopsis*, *Lamium*, *Lapsana*, *Leonurus*, *Leucanthemella*, *Ligularia*, *Linaria*, *Loranthus*, *Lychnis*, *Marrubium*, *Melilotus*, *Molinia*, *Myosoton*, *Neottia*, *Nepeta*, *Neslia*, *Orchis*, *Parasenecio*, *Paris*, *Phlomis*, *Picris*, *Pleurospermum*, *Raphanus*, *Scopolia*, *Serratula*, *Seseli*, *Spergula*, *Tamarix*, *Thymus*, *Trapa*, and *Trigonotis*. Most genera in this category are herbaceous; among the few woody genera are *Caragana*, *Cotoneaster*, *Daphne*, *Syringa*, and *Pyrus*.

3.3.11 Temperate Asia

Included in this category are all the genera restricted to temperate Asia. Their distribution centers are mainly in temperate regions, but they may occasionally occur in subtropical regions. Thirty-six genera of vascular plants in Northeast Asia belong to this category, including *Ajania*, *Amblynotus*, *Arctogeron*, *Bergenia*, *Calloscordum*, *Craniospermum*, *Dimorphostemon*, *Eriocycla*, *Exochorda*, *Gueldenstaedtia*, *Kalimeris*, *Kitagawia*, *Leptopyrum*, *Limnas*, *Macropodium*, *Megadenia*, *Olgaea*, *Phlojodicarpus*, *Pterocarya*, *Saposhnikovia*, *Schizonepeta*, *Spodiopogon*, *Stellera*, *Stevenia*, and *Synurus*.

3.3.12 Mediterranean, western Asia to central Asia

Genera in this category occur mainly in the broad region including the Mediterranean borderlands, western Asia, and central Asia. About 20 of these genera extend eastward to Northeast Asia, including *Aeluropus*, *Alyssum*, *Anthemis*, *Asperugo*, *Bunias*, *Camelina*, *Chorispora*, *Cichorium*, *Goniolimon*, *Hypecoum*, *Kalidium*, *Leontice*, *Nonea*, *Odontites*, *Ptilotrichum*, and *Sphaerophysa*.

3.3.13 Central Asia

Genera in this category occur mainly in dry areas of central Asia. In Northeast Asia, 13 genera fall into this category, e.g. *Cannabis*, *Dontostemon*, *Ledebouriella*, *Lophanthus*, *Sphallerocarpus*, and *Stenosolenium*.

3.3.14 Eastern Asia

The genera in this category include all those listed under the heading “Eastern Asia” and most of those listed under “Chinese endemic” in Wu (1991). They occur mainly in warm-temperate to subtropical regions. For a few genera, however, placement into this category or into that of temperate Asia is difficult and may be ambiguous. About 660 vascular genera in the world belong to this category (H. Qian, unpublished data).

The flora of Northeast Asia has 118 genera that belong to this category. Many are common in warm-temperate and subtropical regions of mainland China, southern Korea, or southern Japan, but occur only in the southern part of Northeast Asia. Forty of the 118 genera range from the Himalayan region eastward to Japan, including *Actinostemma*, *Ainsliaea*, *Amitostigma*, *Aucuba*, *Bothriospermum*, *Cardiocrinum*, *Caryopteris*, *Cephalotaxus*, *Chelonopsis*, *Codonopsis*, *Eccoilopus*, *Eleutherococcus*, *Enkianthus*, *Euryale*, *Evodiopanax*, *Helwingia*, *Heteropappus*, *Ixeridium*, *Koelreuteria*, *Kummerowia*, *Leucosceptrum*, *Lycoris*, *Mosla*, *Neillia*, *Ophiopogon*, *Oreorchis*, *Paraixeris*, *Peracarpa*, *Phtheirospermum*, *Pseudocystopteris*, *Rehmannia*, *Schizopepon*, *Skimmia*, *Stachyurus*, *Tricyrtis*, *Yoania*, and *Youngia*. Another 40 genera occur from mainland China to Japan but do not occur in the Himalayan region. These genera include *Akebia*, *Atractylodes*, *Berteroella*, *Brylkinia*, *Callistephus*, *Cercidiphyllum*, *Corchoropsis*, *Cremastra*, *Deinostema*, *Euscaphis*, *Heloniopsis*, *Hololeion*, *Hosta*, *Hovenia*, *Hylomecon*, *Kalopanax*, *Kerria*, *Leptorumohra*, *Liriope*, *Metanarthecium*, *Metaplexis*, *Miyamayomena*, *Phacellanthus*, *Phellodendron*, *Physaliastrum*, *Pinellia*, *Platycodon*, *Pleurosoriopsis*, *Pseudosasa*, *Rhodotypos*, *Rodgersia*, *Rupiphila*, *Sasa*, *Sasamorpha*, *Schizophragma*, *Stephanandra*, *Trapella*, and *Tripterygium*. The remaining 38 genera are re-

stricted either to continental eastern Asia (e.g. *Belamcanda*, *Crawfurdia*, *Orthoraphium*, *Prinsepia*, *Siphonostegia*, *Streptolirion*, and *Syneilesis*) or to the surrounding islands (e.g. *Botryostege*, *Chamaele*, *Dactylostalix*, *Eleorchis*, *Glaucidium*, and *Japonolirion*).

3.4 Floristic relationships between Northeast Asia and neighboring areas at the species level

Northeast Asia has, as expected, a closer floristic relationship with the rest of Eurasia than with North America. Thirty-nine percent of the 4953 species in Northeast Asia are also present in the neighboring region to the west (i.e. eastern Siberia plus Mongolia), and 24% of these species occur further west in Europe (Fig. 4.3). In contrast, only 16.2% of the species in Northeast Asia also occur in western North America and 12.4% in eastern North America (Fig. 4.3).

Although the southern part of Northeast Asia shares more species with the six longitudinal zones to the east and west than does the northern part (Fig. 4.3), the proportion of shared species is lower. For example, 51% and 35% of the species in the northern part of Northeast Asia occur in western Eurasia (Europe) and in eastern North America, respectively, but only 23% and 11% of the species in the southern part of Northeast Asia also occur in the two other zones (Fig. 4.3). About 24% (290) of the 1220 species in the northern part of Northeast Asia occur in all six longitudinal zones, and most of them are circum-polar or circum-boreal species. Many also occur at high elevations in the southern part of Northeast Asia, e.g. *Arctostaphylos alpina*, *Dryas octopetala*, *Poa alpina*, *P. arctica*, *Rubus arcticus*, *Salix bebbiana*, *Vaccinium oxycoccos*, *V. uliginosum*, and *V. vitis-idaea*. Of the 4953 species in Northeast Asia, 3029, 1696, and 241 species also occur in the warm-temperate, subtropical, and tropical zones to the south, respectively. Almost all of these species are from the southern part of Northeast Asia. In the northern part of Northeast Asia, the numbers of species that reach the same three zones are 422, 185, and 17, respectively, or 34.6%, 15.2%, and 1.4% of the total flora of the northern part of Northeast Asia (Fig. 4.4).

3.5 Floristic relationships among regions within Northeast Asia

Within Northeast Asia, the region with the lowest taxonomic richness (region A) shares a minimum of 64% of its genera and 9% of its species with the region of highest richness (region O); the highest percentage of sharing, on the other hand, is 99% and 92% (between regions B and D). Sørensen similarity indices indicate that the closest floristic relationship is between regions G and H, followed by regions D and E, at both genus (0.94 and 0.91, respectively) and species (0.88 and 0.82) levels. The indices between regions A and O and between regions B and O are the lowest among all possible pairwise comparisons, at both genus (0.33 and 0.31) and species (both 0.06) levels (Tables 4.4 and 4.5).

Although the southern part of Northeast Asia shares more species with the six longitudinal zones to the east and west than does the northern part (Fig. 4.3), the proportion of shared species is lower. For example, 51% and 35% of the species in the northern part of Northeast Asia occur in western Eurasia (Europe) and in eastern North America, respectively, but only 23% and 11% of the species in the southern part of Northeast Asia also occur in the two other zones (Fig. 4.3). About 24% (290) of the 1220 species in the northern part of Northeast Asia occur in all six longitudinal zones, and most of them are circum-polar or circum-boreal species. Many also occur at high elevation in the southern part of Northeast Asia, e.g. *Arctostaphylos alpina*, *Dryas octopetala*, *Poa alpina*, *P. arctica*, *Rubus arcticus*, *Salix bebbiana*, *Vaccinium oxycoccos*, *V. uliginosum*, and *V. vitis-idaea*.

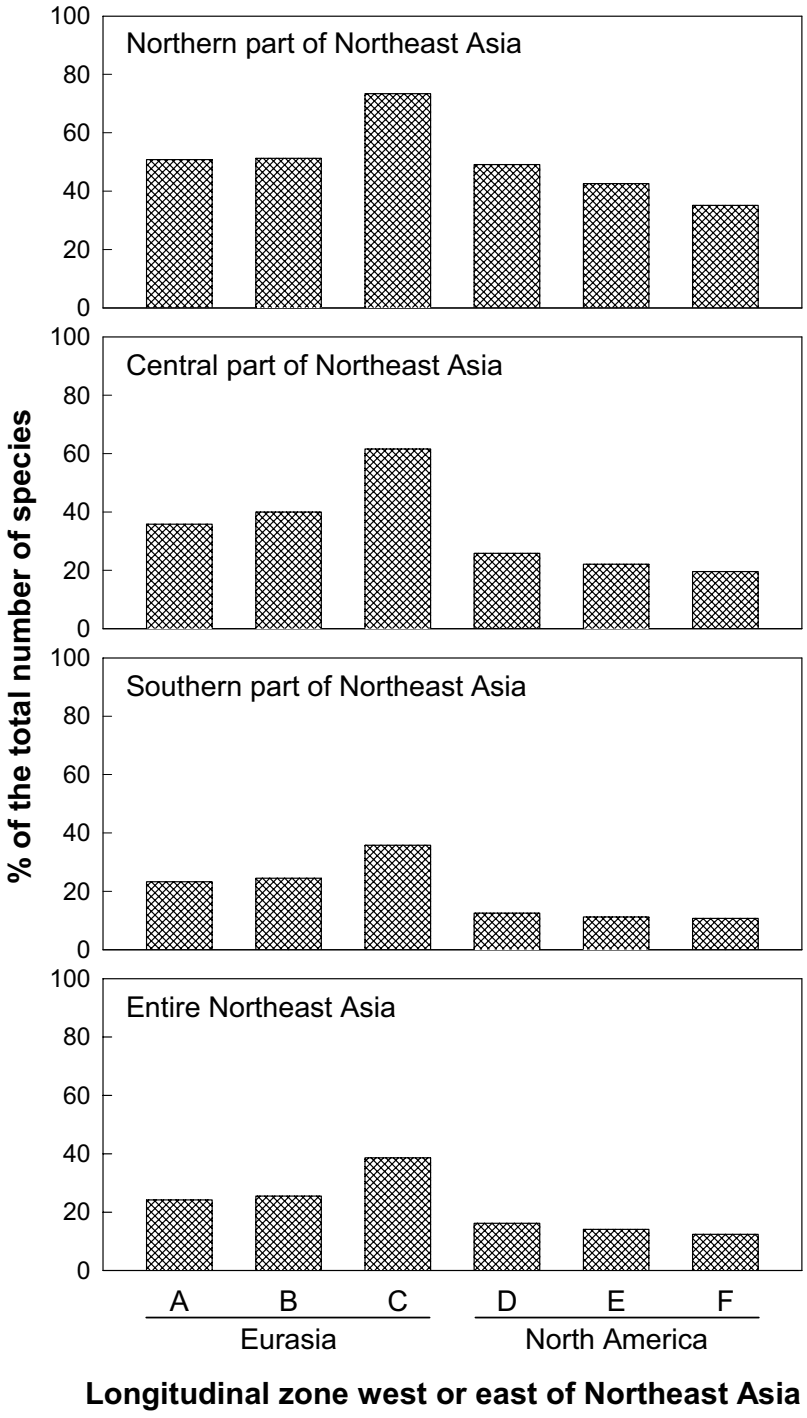

Figure 4.3. Proportion (%) of the species in Northeast Asia, by its three latitudinal zones (northern, central, and southern), occurring in six longitudinal zones of the Northern Hemisphere: A = Europe, B = western Siberia plus Central Asia, C = eastern Siberia plus Mongolia, D = western North America, E = central North America, F = eastern North America.

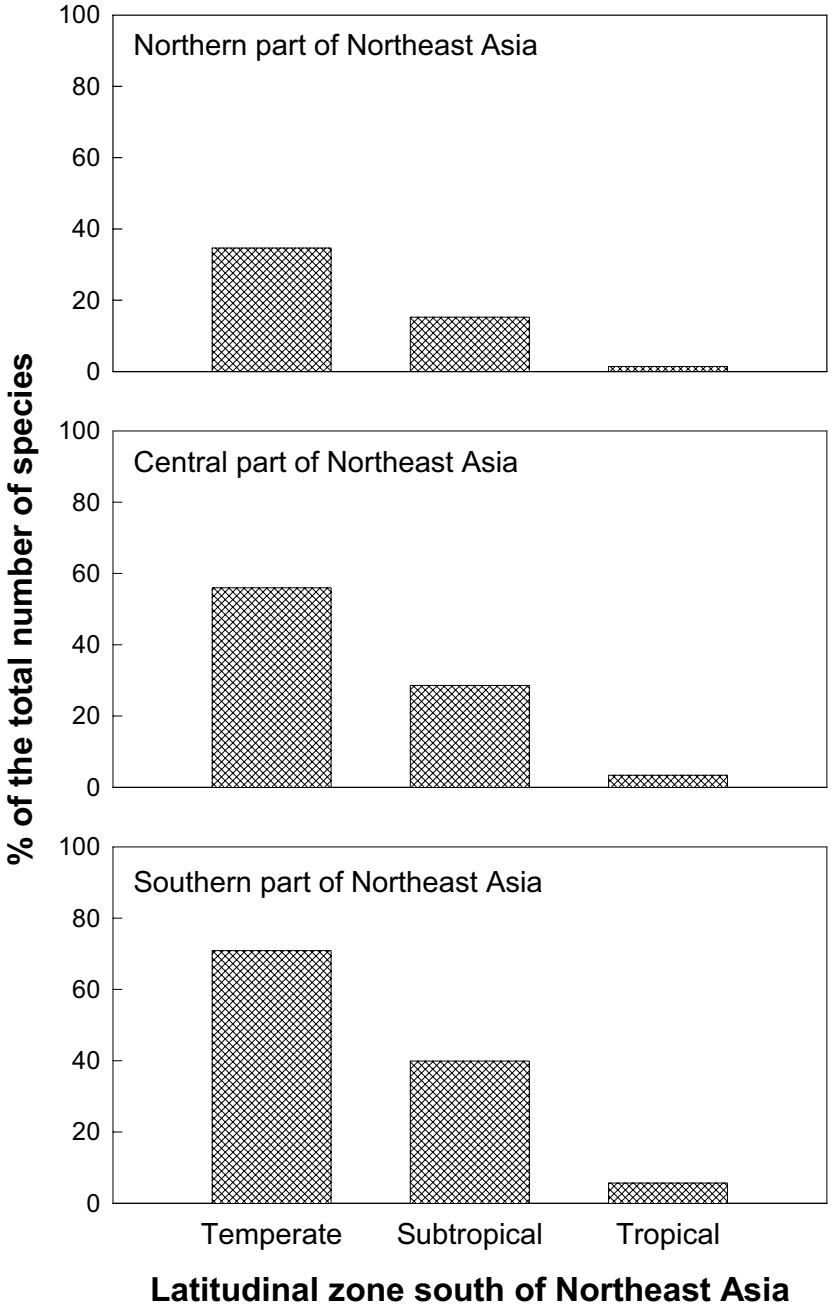

Figure 4.4. Proportion (%) of species in Northeast Asia, by latitudinal zones, that occur in the next three latitudinal zones to the south in eastern Asia (temperate, subtropical, and tropical).

Table 4.4. Sørensen similarity indices (lower-left triangle) and Simpson similarity indices (upper-right triangle) for pairwise comparisons between regional floras within Northeast Asia at the genus level. Codes for regions are the same as in Table 4.1.

Region	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A		0.93	0.92	0.96	0.93	0.81	0.90	0.88	0.87	0.83	0.88	0.83	0.77	0.77	0.64	0.70	0.78	0.82
B	0.86		0.96	0.99	0.97	0.89	0.92	0.90	0.90	0.88	0.92	0.84	0.83	0.83	0.67	0.74	0.80	0.85
C	0.88	0.84		0.97	0.95	0.86	0.94	0.92	0.91	0.87	0.91	0.87	0.81	0.81	0.67	0.73	0.81	0.86
D	0.80	0.76	0.85		0.92	0.82	0.85	0.83	0.87	0.85	0.90	0.82	0.78	0.80	0.65	0.70	0.78	0.82
E	0.76	0.73	0.82	0.91		0.86	0.83	0.81	0.90	0.88	0.92	0.84	0.79	0.82	0.66	0.70	0.80	0.85
F	0.61	0.60	0.68	0.75	0.79		0.77	0.76	0.87	0.97	0.97	0.80	0.88	0.91	0.77	0.81	0.88	0.85
G	0.73	0.68	0.80	0.83	0.82	0.72		0.95	0.90	0.86	0.92	0.91	0.75	0.82	0.66	0.70	0.81	0.89
H	0.72	0.67	0.79	0.81	0.80	0.70	0.94		0.90	0.84	0.92	0.90	0.74	0.81	0.67	0.69	0.80	0.89
I	0.58	0.54	0.64	0.72	0.76	0.80	0.77	0.75		0.89	0.96	0.85	0.74	0.85	0.73	0.72	0.84	0.88
J	0.49	0.46	0.55	0.63	0.67	0.80	0.65	0.64	0.81		0.97	0.79	0.88	0.90	0.78	0.76	0.86	0.81
K	0.46	0.43	0.50	0.59	0.62	0.72	0.62	0.61	0.79	0.88		0.89	0.90	0.86	0.76	0.82	0.83	0.79
L	0.51	0.47	0.57	0.64	0.66	0.69	0.72	0.71	0.81	0.76	0.78		0.69	0.81	0.70	0.65	0.82	0.95
M	0.52	0.50	0.57	0.64	0.66	0.80	0.63	0.62	0.73	0.80	0.74	0.65		0.90	0.83	0.88	0.85	0.78
N	0.40	0.38	0.45	0.53	0.56	0.68	0.56	0.54	0.70	0.83	0.86	0.71	0.74		0.82	0.83	0.87	0.77
O	0.33	0.31	0.37	0.42	0.44	0.57	0.44	0.44	0.60	0.70	0.75	0.61	0.67	0.81		0.87	0.80	0.69
P	0.41	0.39	0.45	0.51	0.52	0.66	0.52	0.52	0.65	0.75	0.76	0.62	0.79	0.77	0.80		0.79	0.69
Q	0.39	0.36	0.43	0.50	0.52	0.64	0.53	0.52	0.68	0.76	0.81	0.70	0.68	0.85	0.79	0.71		0.78
R	0.41	0.38	0.46	0.52	0.56	0.61	0.59	0.58	0.70	0.72	0.77	0.81	0.62	0.75	0.68	0.62	0.78	

Table 4.5. Sørensen similarity indices (lower-left triangle) and Simpson similarity indices (upper-right triangle) for pairwise comparisons between regional floras within Northeast Asia at the species level. Codes for regions are the same as in Table 4.1.

Region	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A		0.89	0.78	0.79	0.67	0.41	0.64	0.59	0.48	0.37	0.40	0.35	0.26	0.26	0.09	0.17	0.22	0.26
B	0.75		0.86	0.92	0.79	0.54	0.73	0.68	0.56	0.50	0.46	0.39	0.37	0.35	0.11	0.23	0.28	0.30
C	0.78	0.73		0.88	0.76	0.50	0.79	0.75	0.60	0.48	0.51	0.48	0.34	0.36	0.14	0.22	0.30	0.36
D	0.67	0.65	0.75		0.83	0.53	0.73	0.68	0.61	0.52	0.53	0.45	0.37	0.38	0.17	0.26	0.30	0.34
E	0.59	0.57	0.65	0.82		0.60	0.67	0.63	0.69	0.61	0.61	0.49	0.42	0.43	0.19	0.29	0.33	0.37
F	0.35	0.38	0.42	0.53	0.60		0.48	0.45	0.70	0.88	0.83	0.48	0.64	0.66	0.39	0.52	0.47	0.39
G	0.59	0.56	0.72	0.68	0.63	0.45		0.89	0.67	0.51	0.57	0.62	0.34	0.42	0.19	0.25	0.36	0.47
H	0.54	0.52	0.68	0.64	0.60	0.43	0.88		0.67	0.49	0.58	0.65	0.34	0.41	0.19	0.25	0.36	0.50
I	0.37	0.35	0.46	0.55	0.61	0.63	0.57	0.57		0.69	0.79	0.64	0.47	0.56	0.32	0.38	0.46	0.51
J	0.26	0.28	0.33	0.43	0.49	0.73	0.39	0.37	0.64		0.88	0.50	0.70	0.72	0.48	0.55	0.54	0.41
K	0.22	0.20	0.28	0.36	0.41	0.57	0.36	0.37	0.61	0.75		0.65	0.71	0.71	0.58	0.60	0.60	0.48
L	0.26	0.24	0.36	0.40	0.42	0.43	0.51	0.54	0.62	0.47	0.52		0.36	0.51	0.30	0.31	0.46	0.68
M	0.21	0.24	0.26	0.34	0.38	0.60	0.30	0.29	0.46	0.63	0.53	0.34		0.77	0.56	0.75	0.53	0.37
N	0.15	0.16	0.20	0.27	0.30	0.47	0.27	0.27	0.45	0.63	0.69	0.41	0.59		0.72	0.70	0.66	0.45
O	0.06	0.06	0.09	0.13	0.14	0.30	0.13	0.14	0.28	0.45	0.52	0.27	0.47	0.66		0.67	0.58	0.35
P	0.11	0.12	0.15	0.21	0.23	0.43	0.19	0.19	0.35	0.54	0.52	0.28	0.66	0.62	0.65		0.48	0.32
Q	0.13	0.13	0.18	0.22	0.23	0.35	0.24	0.24	0.37	0.48	0.57	0.38	0.42	0.64	0.55	0.44		0.50
R	0.16	0.15	0.22	0.25	0.27	0.29	0.32	0.34	0.42	0.38	0.45	0.58	0.30	0.43	0.33	0.29	0.50	

Table 4.6. Distances between regional floras in the 3-D NMDS ordination space at the genus level. Distances in the lower-left triangle were based on presence/absence data and those on the upper-right triangle based on species richness data. Regional codes are as in Table 4.1.

Region	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A		0.38	0.32	0.59	0.83	1.48	0.77	0.80	1.47	1.91	2.26	1.76	1.89	2.41	2.79	2.35	2.41	2.27
B	0.29		0.53	0.74	0.97	1.55	1.03	1.07	1.65	2.05	2.44	2.02	1.93	2.57	2.93	2.41	2.62	2.54
C	0.31	0.55		0.30	0.53	1.20	0.50	0.54	1.19	1.66	2.01	1.51	1.66	2.17	2.60	2.14	2.21	2.05
D	0.65	0.84	0.36		0.25	0.90	0.41	0.47	0.92	1.36	1.73	1.30	1.36	1.88	2.32	1.85	1.95	1.83
E	0.85	1.03	0.56	0.20		0.68	0.41	0.46	0.71	1.15	1.52	1.12	1.18	1.69	2.16	1.68	1.78	1.66
F	1.51	1.61	1.25	0.90	0.73		1.00	1.04	0.52	0.62	1.03	1.04	0.57	1.18	1.64	1.10	1.40	1.44
G	0.95	1.20	0.67	0.50	0.50	1.00		0.06	0.82	1.35	1.64	1.04	1.51	1.84	2.35	1.97	1.86	1.60
H	0.99	1.24	0.71	0.54	0.54	1.04	0.08		0.82	1.36	1.63	1.01	1.54	1.83	2.35	1.98	1.84	1.57
I	1.63	1.80	1.35	1.03	0.88	0.59	0.81	0.83		0.55	0.83	0.54	0.89	1.03	1.60	1.27	1.14	1.00
J	2.01	2.12	1.76	1.44	1.30	0.70	1.34	1.37	0.58		0.43	0.82	0.57	0.56	1.11	0.78	0.82	0.98
K	2.16	2.28	1.93	1.64	1.52	1.01	1.47	1.50	0.75	0.33		0.83	0.94	0.29	0.97	0.93	0.56	0.72
L	1.90	2.10	1.65	1.40	1.31	1.13	1.04	1.05	0.56	0.81	0.73		1.33	1.06	1.68	1.57	1.03	0.58
M	1.88	1.92	1.67	1.36	1.23	0.57	1.47	1.52	0.93	0.60	0.87	1.33		0.95	1.21	0.57	1.24	1.54
N	2.38	2.47	2.16	1.88	1.77	1.21	1.75	1.79	1.05	0.54	0.32	1.02	0.92		0.69	0.77	0.42	0.87
O	2.68	2.73	2.51	2.27	2.19	1.65	2.19	2.25	1.58	1.07	0.88	1.53	1.23	0.58		0.71	0.75	1.43
P	2.34	2.36	2.17	1.91	1.81	1.22	1.96	2.01	1.37	0.85	0.88	1.55	0.70	0.69	0.64		1.03	1.57
Q	2.40	2.49	2.21	1.98	1.90	1.48	1.79	1.84	1.22	0.87	0.57	1.02	1.26	0.45	0.60	0.95		0.70
R	2.34	2.51	2.13	1.90	1.82	1.54	1.56	1.58	1.05	0.99	0.72	0.57	1.55	0.86	1.25	1.50	0.68	

Table 4.7. Distances between regional floras in the 3-D NMDS ordination space at the species level based on presence/absence data. Regional codes are the same as in Table 4.1.

Region	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
B	0.31																
C	0.31	0.40															
D	0.55	0.61	0.34														
E	0.75	0.84	0.58	0.25													
F	1.41	1.38	1.21	0.88	0.72												
G	0.77	0.87	0.49	0.50	0.60	1.13											
H	0.85	0.96	0.58	0.60	0.69	1.19	0.10										
I	1.39	1.45	1.13	0.86	0.70	0.61	0.82	0.83									
J	1.79	1.76	1.54	1.24	1.09	0.48	1.33	1.36	0.63								
K	2.00	2.00	1.74	1.45	1.31	0.80	1.44	1.44	0.70	0.34							
L	1.71	1.80	1.43	1.27	1.19	1.21	0.97	0.91	0.63	1.05	0.91						
M	1.98	1.87	1.76	1.48	1.39	0.73	1.67	1.71	1.14	0.58	0.82	1.57					
N	2.31	2.25	2.03	1.78	1.67	1.09	1.77	1.77	1.13	0.64	0.48	1.26	0.72				
O	2.85	2.78	2.58	2.31	2.19	1.56	2.31	2.32	1.64	1.11	0.95	1.73	1.07	0.55			
P	2.54	2.44	2.30	2.02	1.89	1.20	2.14	2.17	1.48	0.86	0.90	1.79	0.59	0.60	0.59		
Q	2.45	2.37	2.15	1.97	1.92	1.50	1.83	1.81	1.39	1.10	0.91	1.30	1.16	0.60	0.84	1.10	
R	2.28	2.31	1.98	1.85	1.81	1.67	1.53	1.47	1.22	1.35	1.09	0.74	1.72	1.18	1.52	1.78	0.90

Of the 4953 species in Northeast Asia, 3029, 1696, and 241 species also occur in the warm-temperate, subtropical, and tropical zones to the south, respectively. Almost all of these species are from the southern part of Northeast Asia. In the northern part of Northeast Asia, the numbers of species that reach the same three zones are 422, 185, and 17, respectively, or 34.6%, 15.2%, and 1.4% of the total flora of the northern part of Northeast Asia (Fig. 4.4).

In general, the results from different NMDS ordination analyses on the floristic relationships among the 18 regions agreed very well, not only with each other (comparing Figs. 4.5, 4.6, and 4.7; Tables 4.6 and 4.7) but also with the results from the similarity analyses. For example, the floristic distances between regions G and H and between regions D and E are the shortest in the 3-D NMDS ordination space, indicating the closest floristic relationship; distances between regions A and O and regions B and O are the longest, at both the genus (Figs. 4.5 and 4.6; Table 4.6) and species level (Fig. 4.7; Table 4.7).

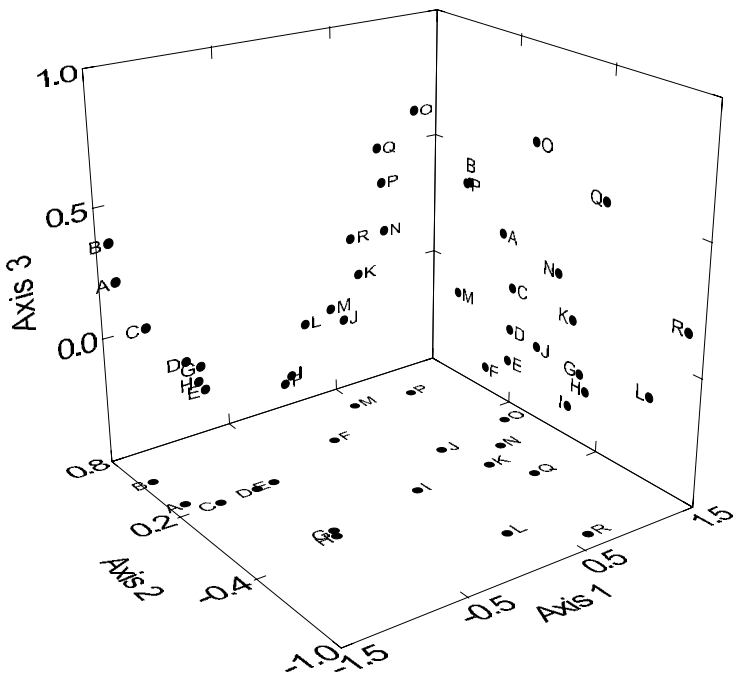

Figure 4.5. Ordination, by non-metric multi-dimensional scaling (NMDS), of the 18 regions of Northeast Asia using genus presence/absence data. Regional codes are as in Table 4.1.

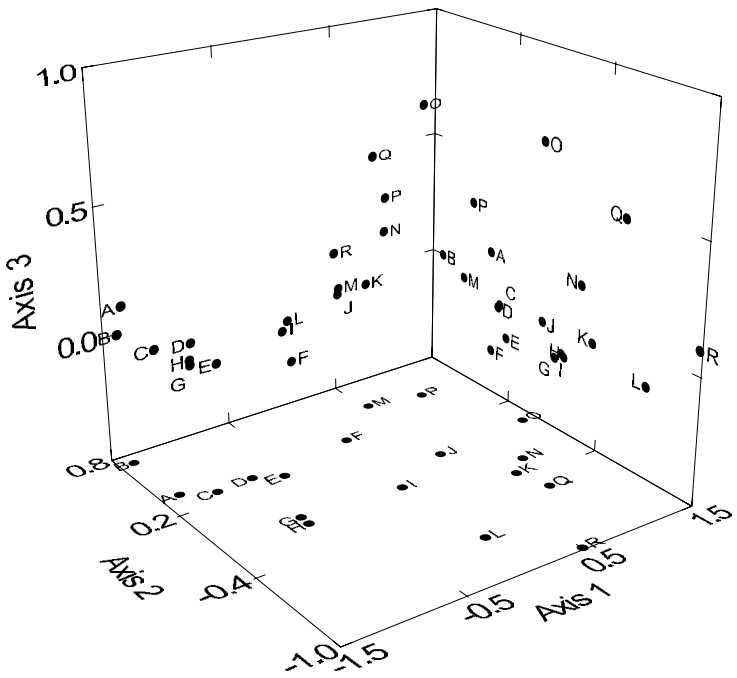

Figure 4.6. Ordination, by non-metric multi-dimensional scaling (NMDS), of the 18 regions of Northeast Asia based on the number of species in each genus. Regional codes are as in Table 4.1.

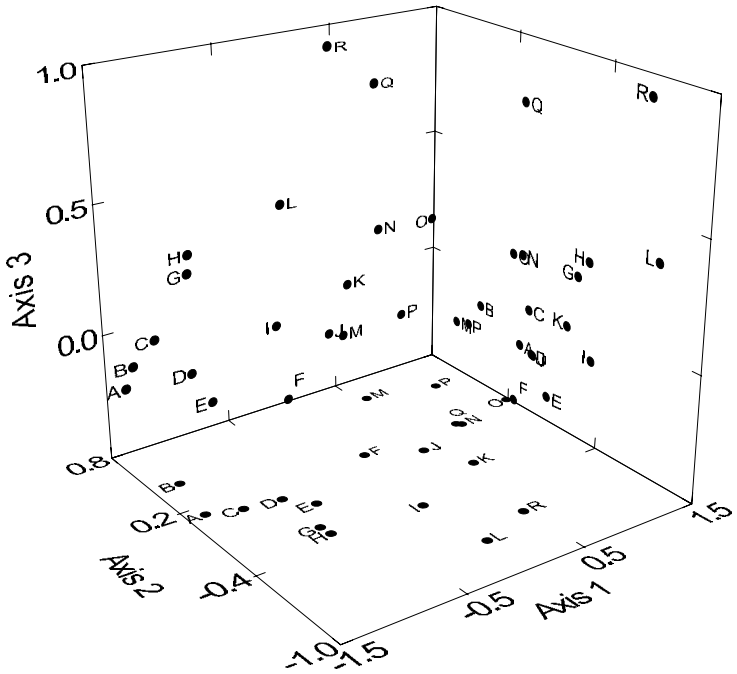

Figure 4.7. Ordination, by non-metric multi-dimensional scaling (NMDS), of the 18 regions of Northeast Asia using species presence/absence data. Regional codes are as in Table 4.1.

3.6 Description of geographic regions within Northeast Asia

3.6.1 Chukotka region (Region A, Fig. 4.1)

This region lies in easternmost Arctic Eurasia and includes, as defined by Yurtsev (1974), the Chukotka Peninsula and Wrangel and Gerald Islands. The region contains extensive lowlands along the lower Anadyr River and along the coast of the Chukotian Sea. In the interior, mountainous terrain prevails. The mountain chains are oriented east-west and reach elevations of up to 1843 m (Chantal'skiy mountain range). Among the largest rivers are the Anadyr (in the Bering Sea Basin) and Amguema Rivers (in the Chukotian Sea Basin).

The northern part, including Wrangel Island and the coasts of the East Siberian Sea and Chukotian Sea, has a typical arctic climate, characterized as perhumid, with short, cool summers and long, cold winters. Mean annual temperatures along the East Siberian Sea range from −10 to −14°C. Mean January temperatures range from −27 to −32°C and mean July temperatures from 4 to 7°C. Along the Bering Sea coast, the slightly milder climate has mean annual temperatures ranging from −5 to −8°C; January and July mean temperatures here range from −14 to −23°C, and from 5 to 10°C, respectively. Average annual precipitation varies from 136 mm at Pevek (on the coast of the East Siberian Sea) to 540 mm on Cape Navarin. Despite the low precipitation, cold temperatures and very low evapotranspiration rates result in perhumid conditions.

The main vegetation is typical arctic tundra, dominated by grasses, sedges, and ericaceous shrubs. Ericaceous tundra is common on upland sites where the water table is below the surface for most of the growing season. The ericaceous tundra is dominated by a low shrub layer (5–10 cm) of *Arctostaphylos alpina*, *Diapensia lapponica* var. *obovata*, *Loiseleuria procumbens*, *Ledum palustre* ssp. *decumbens*, *Vaccinium vitis-idaea*, *V. uliginosum*, *Empetrum nigrum*, *Dryas octopetala*, and *Salix reticulata*, and various kinds of mosses and lichens, which belong to *Cladina*, *Cladonia*, *Cetraria*, *Stereocaulon*, *Racomitrium*, *Polytrichum*, and *Dicranum*. On upper slopes, lichen tundra is widespread, dominated mostly by various *Cladina* species. Wet hummocky sedge tundra is common on the lowlands. The main sedges, *Eriophorum vaginatum* and *Carex atrofusca*, form small tussocks 15–20 cm tall. Patches of *Sphagnum* commonly occur between the sedge tussocks. Shrub species in this type of tundra include *Betula nana* ssp. *exilis*, *Ledum palustre* ssp. *decumbens*, *Salix arctica*, and *Vaccinium uliginosum*. The region is generally treeless. Patches of small, stunted *Chosenia arbutifolia* and *Populus suaveolens* only occur in river valleys and on lower slopes near the southern boundary, areas that are well protected from strong winds. In montane areas, integrated tundra communities reach elevations of 200–400 m, and single plants can be found up to 600 m. Higher areas are generally barren or covered with snow patches throughout the summer.

Endemic vascular species in this region include *Arctanthemum integrifolium*, *Cardamine sphenophylla*, *Hedysarum mackenzii*, *Oxytropis beringensis*, *O. kateninii*, *O. sverdrupii*, *O. uschakovii*, *O. wrangelii*, *Papaver atrovirens*, *P. chionophilum*, *P. gorodkovii*, *P. multiradiatum*, *P. uschakovii*, *Poa arctostepporum*, *Potentilla beringensis*, *P. villosula*, *P. wrangelii*, *Ranunculus punctatus*, *Saxifraga arctolitoralis*, *Solidago compacta*, *Suaeda arctica*, *Taraxacum anadyrense*, *T. czukoticum*, *T. leucocarpum*, *T. nanaunii*, *T. pseudoplatylepium*, *T. senjavinense*, *T. tolmaczevii*, *T. uschakovii*, and *T. wrangelicum*.

3.6.2 Anuj (Region B, Fig. 4.1)

Most of the Anuj region is mountainous, with highly dissected topography and absolute

elevations of 2500–2900 m. The valleys of the Anuj and Omolon Rivers are wide and have alluvial deposits. The elevation difference from valley bottoms to mountaintops ranges from 300 to 500 m. The region does not have any marine borders.

The climate of most of the region is severe continental subarctic, with very striking seasonality due to interactions between Asian anticyclones and Aleutian cyclones. Annual precipitation is 300–500 mm, while mean annual temperature ranges from −11 to −12°C. The mean temperature of the coldest month (January) is between −30 and −36°C and that of the warmest month (July) between 13 and 14°C. Freezing temperatures can start as early as mid-September, and the recorded extreme minimum temperature is −60°C.

Boreal forests of *Larix gmelinii* prevail in the region. The vertical zonation is from a mosaic of open *L. gmelinii* woodlands, *Pinus pumila* thickets, and tundra at lower elevations, to *Pinus pumila* thickets at middle elevations and alpine tundra at higher elevations. The northern limit of *Larix gmelinii* lies in the basin of the Maliy Anuj River, at about 68°N. In the south (e.g. near the Omolon River), *L. gmelinii* reaches 800–900 m in elevation, while in the north (e.g. near the Anuj River), the timberline reaches 200–300 m. The elevation of timberline also tends to decrease from west to east, with increasing proximity to the Bering Sea. The larch woodlands typically have a very sparse canopy of *L. gmelinii* (cover 5–10%), a layer of *Pinus pumila* covering 60–100% (with an admixture of *Betula divaricata* and *Alnus viridis* ssp. *fruticosa*), and a dwarf shrub-herb layer of *Loiseleuria procumbens*, *Arctostaphylos alpina*, *Empetrum nigrum*, *Polygonum tripterocarpum* and *Epilobium angustifolium*. On steeper slopes the ground in the larch woodlands is covered with lichens, typically *Cladina mitis*, *Cladina rangiferina*, and *Cladina stellaris*. In large river valleys with alluvial deposits, *Chosenia arbutifolia* and *Populus suaveolens* form closed forest stands (8–10 m tall) with grasses, forbs and horsetails dominating in the herb layer. Forest stands in river valleys are typically species-rich, with the number of vascular species in a plot of 400 m^2 frequently reaching 50–60. Vascular endemic species in this region include *Chrysosplenium arctomontanum*.

3.6.3 Koryakia (Region C, Fig. 4.1)

This region includes the eastern slopes of the Kolymskiy Range (highest elevation 1800 m), the plains of the upper Anadyr River (Bering Sea Basin), the Penzhina River (Sea of Okhotsk Basin), and the Koryakskiy upland (reaching 2562 m), which lies between the Bering Sea coast and the Kamchatka Peninsula. The eastern region borders the Bering Sea and the southwestern part borders the Sea of Okhotsk and Penzhina Bay.

The climate of the region is subarctic, influenced by the Pacific monsoon. Within the region the climate changes from submaritime in the west to maritime on the coast of the Bering Sea. Mean annual temperature ranges from −4.1 to −4.6°C, with freezing temperatures starting by the end of September. Mean January temperature does not fall below −13 to −16°C in the coastal areas. The warmest month is August, with mean temperature reaching 8.0–8.6°C. Due to the cold water with lingering sea ice, this region receives less precipitation than Kamchatka to the south. Annual precipitation ranges from 300 mm in the interior to 700 mm on the coast, but may reach 900 mm at higher elevations. Most precipitation falls in summer.

Main vegetation types in this region are the *Pinus pumila* thickets in the interior and *Alnus viridis* ssp. *fruticosa* thickets with scattered trees of *Larix gmelinii* on the coast. These thickets are widely distributed on lower mountain slopes and in well-drained plains. *L. gmelinii* occurs sporadically in the interior thickets and gradually decreases in abundance toward the coast, where it is absent. The thickets generally have a closed canopy (3–6 m tall); a very sparse shrub layer dominated by *Spiraea beauverdiana*, *Rosa amblyotis*,

and/or *R. acicularis*; and a herb layer whose composition varies with site conditions. On mesic sites, the herb layer is dominated by *Calamagrostis purpurea* and the moss layer by *Hylocomium splendens* and *Pleurozium schreberi*. *Dryopteris expansa* is a characteristic species in the *Alnus* thickets, and *Maianthemum bifolium* is a characteristic species in the *Pinus* thickets on mesic sites. On windward slopes and in frost pockets, patches of tundra vegetation are commonly found, particularly toward the north. On sites protected from strong wind and on well-insolated slopes, particularly in the south, *Larix gmelinii* may form closed patchy communities. On poorly drained wetlands, *Eriophorum-Carex* tundra communities are common. *Chosenia arbutifolia* and *Populus suaveolens* forests develop in the valleys of large rivers, where alluvial deposits are deep. Two vertical vegetation belts can be distinguished: an *Alnus viridis* ssp. *fruticosa* and *Pinus pumila* belt from hill base up to 600–800 m, followed by alpine tundra up to 1000 m.

Endemic vascular species in this region include *Corispermum maynense*, *Gastrolychnis soczaviana*, *Sparganium probatovae*, *Taraxacum korjakense*, and *Tephroseris schistosa*.

3.6.4 Kolyma–Northern Okhotsk region (Region D, Fig. 4.1)

This region includes the upper Kolyma River basin, the southeastern end of the Cherskogo mountain range and the southern half of the Kolymskiy mountain range. The southern border of the region follows the Suntar-Hayat range, the eastern border is that of Magadan, and the northern border follows the upper Omolon River basin across to the northern end of Penzhina Bay. The southeastern portion of the region borders the Sea of Okhotsk. Elevations range from the sea level up to 2959 m (Mt. Mus-Haya, in the Suntar-Hayat mountains). The peaks of the Kolymskiy range are 600–1200 m high, and the eastern spurs of the Cherskogo range reach 2500 m.

The climate of the region varies from continental with very cold winters (mean January temperature below −32°C) in the upper Kolyma basin to subcontinental with less cold winters (mean January temperature above −32°C) along the coast of the Sea of Okhotsk. Monsoonal oceanic air masses affect the coast in summer, but the coastal mountains block these from penetrating into the interior. Annual precipitation ranges from 300 mm in the interior to 500 mm on the coast and may exceed 700 mm at higher elevations on the coast. Most of the precipitation falls in summer. Mean annual temperature ranges from −12.3°C (in Oymyakon in the Kolyma basin) to −4.7°C (in Magadan, on the southern coast).

Boreal forests in this region are dominated by *Larix gmelinii*, in combination with thickets of *Pinus pumila* and/or *Alnus viridis* ssp. *fruticosa*. Open *Larix gmelinii* forests with understoreys dominated by lichens and *Pinus pumila* and/or *Alnus viridis* ssp. *fruticosa* thickets occur in the northeast, where *Pinus pumila* thickets prevail at higher elevations. In wetlands and on interior sites with permafrost, open *Larix gmelinii* forests are common, dominated by herbs such as *Calamagrostis purpurea*, *Epilobium angustifolium* and *Carex* spp. in the understorey; meadow communities are also common. Treeline increases from 200–300 m in the north to 500–600 m in the south. On the Sea of Okhotsk coast, small patches of *Betula ermanii* scrub occur on sites facing the sea. Forests dominated by *Chosenia arbutifolia*, *Populus suaveolens*, and *Salix udensis* are common on alluvial deposits along rivers. Three vertical vegetation belts can be identified: a *Larix gmelinii* forest belt reaching 200–300 m in the north and 500–600 m in the south, a *Pinus pumila* thicket belt reaching 1000–1300 m, and an alpine tundra belt reaching 1500 m.

Endemic vascular species in this region include *Astragalus ishigensis*, *Carex pseudodahurica*, *Castilleja variocolorata*, *Chrysosplenium saxatile*, *Corispermum ochotense*, *Delphinium kolymense*, *Draba majae*, *Minuartia*

tricostata, *Oxytropis susumanica*, *Pedicularis kolymensis*, *Poa tzvelevii*, *Potentilla rupifraga*, *Salix khokhriakovii*, *Saussurea tomentosella*, *Taraxacum kolymense*, and *T. subalternilobum*.

3.6.5 Aldan–Southern Okhotsk region (Region E, Fig. 4.1)

This region lies between the Suntar-Hayat mountains in the north and the Stanovoy range in the south. In the east the region borders the Sea of Okhotsk, and in the west its boundary follows the administrative border of the Khabarovskiy Krai. The region includes the Dzhugdzhur mountains, which run along the coast of the Sea of Okhotsk. Among the largest rivers in the region are the Maya (including its tributaries, the Yudoma and Uchur) in the Aldan basin, and the Okhota, Inya, and Tauy Rivers in the basin of the Sea of Okhotsk. Elevations in the region range from sea level to 2959 m (Mt. Mus-Haya, in the Suntar-Hayat mountains).

The climate of the region is influenced by monsoonal Pacific air masses in summer and by continental Asian air masses in winter. The Dzhugdzhur mountains (highest peak about 2000 m) creates a sharp gradient in continentality from severe continental climates in the interior to submaritime climates on the coast. The mean temperature of the warmest month (July) is 16°C in the interior and 12°C on the coast; the mean temperature of the coldest month (January) is −36°C in the interior and −20°C on the coast. Annual precipitation ranges from about 300 mm in the interior to 364 mm on the coast (Okhotsk), most of which falls from May to November.

The zonal vegetation of this region is boreal forest, primarily dominated by *Larix gmelinii*, which occurs on various site types from sea level up to 1000 m. *L. gmelinii* forests with much *Ledum palustre* in the shrub layer prevail on zonal sites. Along large rivers, the main vegetation types include *Larix gmelinii* forests with a herb layer of *Carex appendiculata* and *Epilobium angustifolium*, *Populus suaveolens* forests, *Chosenia arbutifolia* forests, and grassy meadows dominated by *Calamagrostis langsdorffii*. In the interior, in addition to *Larix gmelinii* forests, *Pinus sylvestris* can form pure stands on sandy sites. The upward sequence of vegetation belts in this region is *Larix gmelinii* forests, *Betula ermanii* forests, *Pinus pumila* thickets, and alpine tundra. Elevations of these vegetation belts vary with distance from the coast and with slope aspect.

Endemic vascular species in this region include *Aconitum ochotense*, *Anemone tamarae*, *Astragalus ochotensis*, *Draba magadanensis*, *Euphrasia ajanensis*, *Oxytropis vassilievii*, *Saxifraga lactea*, *S. svetlanae*, *Taraxacum ajanense*, *T. ajano-majense*, *T. magadanicum*, and *T. nudiscaposum*.

3.6.6 Upper Amur (Region F, Fig. 4.1)

This region lies between the Stanovoy mountains in the north and the Amur River and Tukuringra-Dzhagdy mountains in the south. To the west it borders the Amurskaya administrative district and to the east the Zea and Uda River basins. This region is mountainous, with elevations ranging from 100 m (on the Amur River) to 2412 m (in the Stanovoy range). The areas between the Lena and Amur River basins are highlands. Most large mountain ranges in this region run east to west.

The region has continental to subcontinental climates with severe winters. The mean temperature of the warmest month (July) is 16 to 20°C, and that of the coldest month (January) ranges from −28 to −32°C. Even though this is an interior region, it is influenced by Pacific air masses that go up the Amur River valley in summer. In winter the region is controlled by the extensive Siberian anticyclone. The configuration of the mountain systems strongly affects the climate, creating a complex mosaic of local climates. Temperature inversions are common in the mountains, with lower temperatures in valleys and on lower slopes than at higher elevations. Annual pre-

cipitation of the region ranges from 400 to 500 mm.

The zonal vegetation of the region is boreal forest, represented by various types of *Larix gmelinii* forest. Most forest stands in the region have a history of fire. *Pinus sylvestris* stands occur on drier or sandy sites, and is more abundant here than in the Aldan-Southern Okhotian region (section 3.6.5). *Betula platyphylla* forests fringe plains affected by cool-air drainage. In the south, patches of *Quercus mongolica* forest occur on south-facing slopes at mid-elevations (300–500 m). *Picea jezoensis* var. *ajanensis* stands appear as small patches on south-facing slopes throughout the region, usually near timberline. In river valleys the vegetation is dominated by *Populus suaveolens*, *Chosenia arbutifolia*, *Salix rorida*, and *S. udensis*. *Picea abies* ssp. *obovata* may also form stands in valleys. On the wetlands of the upper Zea River basin, *Larix gmelinii* forest occupies extensive areas. These larch forests have open canopies and are dominated by *Carex appendiculata* in the understorey. The upward sequence of vegetation belts in this region involves *Larix gmelinii* reaching 900–1000 m, *Pinus pumila* from 900 to 1300 m, and alpine tundra above 1300 m. In the south, on southerly slopes, the larch forest may be interrupted by broad-leaved *Quercus mongolica* forests at 300–500 m and by dark-conifer *Picea jezoensis* var. *ajanensis* forests at 400–800 m. Endemic vascular species in this region include *Phlomis woroschilowii* and *Taraxacum woroschilovii*.

3.6.7 Kamchatka (Region G, Fig. 4.1)

This region includes Koraginskiy Island in the north and most of the Kamchatka Peninsula, except for the southern end of the peninsula (Cape Lopatka). The region includes two major mountain ranges and an interior valley. The larger Sredinniy range runs throughout the length of the peninsula, the highest elevation is on Mt. Ichinskaya Sopka (3621 m) and other peaks usually reach 1800–2500 m. The smaller but more dissected Vostochniy range runs along the eastern coast and has peaks usually reaching 1500–2000 m. The Vostochiniy range has over 40 active volcanoes, including the volcano Kluchevskoy as the highest peak. The relief on the broad western coastal plain (Okhotsk coast) is gentler than on the more rugged southeastern (Pacific) coast, where volcanoes come close to the sea. The two mountain ranges have a dramatic effect on the climate of the interior Kamchatka River valley.

The geographic complexity of the region results in great climatic differences. Eastern Kamchatka has a more maritime climate, with cold winters but with 15% of winter days above 0°C. Western Kamchatka has colder winters. The frost-free period on the southeastern coast is from 4 to 4.4 months, as compared to 3 months on the western coast. The climate of central Kamchatka is contintental, with very cold winters (January mean temperature −22°C) and warm summers, with a mean growing season of 92 days. Annual precipitation differs greatly across the region but generally increases from north to south. Due to the strong Aleutian Low, the southeastern coast receives over 1000 mm of annual precipitation (up to 1500 mm at higher elevations). In the interior valley, annual precipitation does not exceed 800–900 mm and can be as low as 400 mm. Most of the precipitation falls in winter as snow. The southern coast has much more snowfall, ranging from 100 to 300 cm in depth and limiting soil freezing to a depth of less than 10 cm.

The large climatic differences in the region result in diverse vegetation. In maritime areas, the *Betula ermanii* forest is the zonal vegetation type. On mesic sites, *B. ermanii* stands have well-developed canopies (30–90% cover of *B. ermanii*) and herb layers. On most sites, *B. ermanii* stems are crooked to the height of the snow pack. The breast-height diameter of mature *B. ermanii* trees averages 40 cm but can reach a maximum of 150 cm. The most common species in the shrub layer are *Alnus viridis* ssp. *fruticosa*, *Pinus pumila*, and *Sorbus sambucifolia*. The herb layer contains

various tall forbs, such as *Senecio cannabifolius*, *Ranunculus acris*, and *Urtica dioica* ssp. *platyphylla*. Tall-forb meadows occupy much of the wetland landscape on the west coast and on sites with late-melting snow patches. In these meadows, *Filipendula camtschatica*, *Angelica ursina*, and *Parasenecio hastatus* can reach over 3 m in height. Evergreen boreal forests occur only in interior Kamchatka. *Larix gmelinii* forests with much *Ledum* in the understorey is a zonal vegetation type in the interior, but also *Picea jezoensis* var. *ajanensis* forests with understoreys of mosses or small herbs such as *Maianthemum dilatatum*. River valleys throughout Kamchatka carry forests and scrub of *Populus suaveolens*, *Salix udensis*, and *Chosenia arbutifolia*. The vertical zonation in Kamchatka generally follows the upward sequence of: *Larix gmelinii* and *Picea jezoensis* var. *ajanensis* forests (only in central Kamchatka), *Betula ermanii* forests, *Pinus pumila* and *Alnus viridis* ssp. *fruticosa* thickets with tall-forb meadows, and alpine tundra. The snow line in Kamchatka is generally around 1600 m.

Endemic vascular species in this region include *Aconitum woroschilovii*, *Agrostis pauzhetica*, *Chrysosplenium pacificum*, *Oxytropis littoralis*, *Salix erythrocarpa*, *Taraxacum neokamtschaticum*, *T. rufum*, and *Thymus novograblenovii*.

3.6.8 Commander Islands and Northern Kuril Archipelago (Region H, Fig. 4.1)

This region includes the Commander Islands, the southernmost tip (Cape Lopatka) of the Kamchatka Peninsula, and the northern portion of the Kuril Archipelago. The Commander Islands are located about 250 km off the east coast of Kamchatka, close to the western end of the Aleutian Island chain. The northern Kurils consist of about 30 islands, including (from north to south) Shumshu, Paramushir, Onekotan, Shiashkotan, Ushishir, and Simushir. All of these islands resulted from volcanic events. The highest elevation in the region is 1840 m on Atlasova Island, while the highest point of the Commander Islands is 751 m (Bering Island).

The region has a typical suboceanic climate, with cool summers and cold winters. The mean annual temperature ranges from 1.1°C (at Cape Lopatka) to 2.1°C (on the Commander Islands). The coldest month is February, with mean temperature ranging from −4°C (Nikolskoye on Bering Island) to −6.9°C (at Cape Lopatka). The highest mean temperature also occurs later, in August, but does not exceed 9 to 11°C. Annual precipitation frequently exceeds 1200 mm, distributed relatively evenly among the seasons.

The main vegetation type on the Commander Islands is heath tundra with patches of bog and meadow vegetation. Narrow strips of shrubby willows (e.g. *Salix alaxensis*, *S. udensis*, and *S. glauca*) and dwarf alder (*Alnus viridis* ssp. *fruticosa*) frequently occur along rivers and ravines. There are no trees on the Commander Islands. The vegetation at the southern tip of Kamchatka and in the northern Kuril Islands is mainly *Alnus viridis* ssp. *fruticosa*, *Pinus pumila*, and *Sorbus sambucifolia*. The zonal vegetation is dominated by *Alnus viridis* ssp. *fruticosa*, about 6 m tall, with twisted stems and a basal diameter of 6–25 cm. The herb layer is well developed and dominated by *Dryopteris expansa* and *Glyceria alnasteretum* on mesic sites. *Salix udensis*, the only tree species in this area, usually occurs on leeward slopes adjacent to rivers. Tall-forb meadows composed of *Filipendula camtschatica*, *Senecio cannabifolius*, and *Petasites amplus* prevail on sites with late-melting snow patches. The vertical vegetation belts in this region are the dwarf alder belt reaching 600–900 m and the alpine tundra above. Endemic vascular species in this region include *Oxytropis rubricaudex*, *Potentilla beringii*, *Taraxacum ketoiense*, *T. kojimae*, and *T. shumushuense*.

3.6.9 Amgun and Northern Sakhalin (Region I, Fig. 4.1)

This region is composed of a mainland area, the northern half of Sakhalin Island, and the Shantar Archipelago. On the mainland, the region extends from the eastern Stanovoy mountains to the Dzhugdzhur mountains along the Sea of Okhotsk. The southern boundary runs on the northern spurs of the Bureya and Badzhal mountains until Komsomolsk, then follows the Amur River northeast to Lake Kizi, and then turns east to the Tatarskiy Strait near Cape Orlova. The southern border on Sakhalin Island coincides with Schmidt's line (Tatewaki 1958). Elevations in this region range from the sea level to 2384 m, in the Yam-Alin mountains.

The climate varies from submaritime to maritime boreal, with a striking monsoon character. The mean annual temperature is −3°C. The mean temperature of the warmest month (July) ranges from 12 to 18°C, and that of the coldest month (January) from −35°C in the interior to −25°C in Nikolayevsk on the coast or to −20°C in Okha in northern Sakhalin. Annual precipitation is 500–600 mm, most of which falls in summer.

Zonal vegetation in this region is evergreen boreal forest dominated by *Picea jezoensis* var. *ajanensis* and *Abies nephrolepis*. The abundance of *Abies* increases towards the south, being nearly absent, for example, in the Uda River basin and on the Shantar Islands but increasing to nearly 30% in the Amgun River basin. On the mainland, *Picea-Abies* forests occur on all zonal sites from the sea level to 1000 m in elevation. Patches of *Pinus sylvestris* forest can be found on sandy sites in the central Uda River valley. On northern Sakhalin *Picea-Abies* forests occur only on Schmidt Peninsula and around the town of Nogliki, where *Abies nephrolepis* is replaced by *A. sachalinensis*. *Larix gmelinii* stands dominate on azonal sites (e.g. sites with permafrost or sandy soils). Sandy substrates around Okha, near the tip of Sakhalin, are occupied by *Pinus pumila* communities, particularly at elevations below 100 m. In river valleys throughout the region, the major vegetation types include grass meadows and wet *Larix gmelinii* woodlands, with *Sphagnum* spp. and *Carex appendiculata* in the understorey. *Larix gmelinii* forests tend to replace *Picea* forests on zonal sites after severe wildfire disturbance. Stands dominated by broad-leaved tree species such as *Quercus mongolica*, *Fraxinus mandshurica*, *Tilia amurensis*, and *Betula costata* occur as small patches on south-facing slopes along the Amur River. The vertical vegetation belts, from bottom to top, are: a dark conifer forest belt (dominated by *Picea jezoensis* var. *ajanensis* and *Abies nephrolepis*) reaching 800–900 m, a *Betula ermanii* forest belt ranging from 800 to 1100 m, a *Pinus pumila* forest belt ranging from 1100 to 1200 m, and alpine tundra above 1100–1200 m.

Endemic vascular species in this region include *Artemisia punctigera*, *Astragalus sachalinensis*, *Callianthemum sachalinense*, *Lonicera tolmatchevii*, *Miyakea integrifolia*, *Oxytropis helenae*, *Saxifraga voroschilovii*, *Taraxacum collariatum*, *T. vestitum*, *Thymus schlothaueriae*, and *Valeriana gotvanskyi*.

3.6.10 Middle Amur (Region J, Fig. 4.1)

This region is mostly lowlands, including the lower Zea River basin, the Selemdzha River and Bureya River basins, the upper Amgun River basin, and extensive wet plains in the middle Amur River valley. The Amur River forms the southern and eastern borders of the region. The northern border runs along Mt. Bureya, which is generally less than 2000 m in elevation. Elevations in this region range from 50 m in the Amur River valley to 2167 m on the Bureinskiy range.

The climate of the region is subcontinental, with cold winters and warm summers. Mean annual temperature ranges from −0.1 (in Birobidzhan) to 1.4°C (in Khabarovsk). The mean temperature of the coldest month (January) ranges from −30 to −25°C, and that of the warmest month (July) from 15 to 20°C. An-

nual precipitation ranges from 550 to 650 mm, most of which falls in summer.

Cool-temperate and boreal forests occur throughout the region. Broad-leaved and mixed forests represent the zonal vegetation in the south, particularly in the Amur lowlands. *Pinus koraiensis*, *Quercus mongolica*, *Tilia amurensis*, *Betula davurica*, and *B. costata* are major components of these forests. *Picea-Abies* forests are the zonal vegetation in the Bureinskiy mountains. *Larix gmelinii* forests occupy the upper Bureya and Selemdzha River basins. Despite physiognomic differences in zonal vegetation types, the presence of temperate species in the boreal forests is a characteristic feature of the region. Azonal vegetation in the region includes the extensive grass meadows in the Amur valley. Broad-leaved forests dominated by *Ulmus japonica*, *Fraxinus mandshurica*, and *Juglans mandshurica*, as well as *Populus suaveolens*, *Chosenia arbutifolia*, *Salix rorida*, and *S. udensis*, occur widely in valleys of the various Amur tributaries (e.g. Bureja and Zea Rivers). The vertical vegetation zonation is similar to that of Amgun and northern Sakhalin (region I, section 3.6.9), but the *Betula ermanii* forest belt is poorly represented and is mostly replaced by *Pinus pumila* thickets.

Endemic vascular species in this region include *Aster woroschilovii*, *Carex woroschilowii*, *Corydalis gorinensis*, *Elymus zejensis*, *Erigeron burejensis*, *Leontopodium blagoveshczenskyi*, *Saussurea splendida*, *Saxifraga selemdzhensis*, *Spiraea schlothauerae*, *Taraxacum badzhalense*, and *T. lineare*.

3.6.11 Ussuri (Region K, Fig. 4.1)

The Ussuri region lies on the southern side of the lower Amur River, with its western boundary lying on the Chinese-Russian border along the Ussuri River, one of the biggest tributaries of the Amur. On the east, the region borders the Sea of Japan. The Sikhote-Alin mountain range runs continuously throughout the region. On the eastern side it has a steep escarpment to the sea, and on the western side it has gentler slopes that reach the Ussuri-Khanka lowland. The highest elevation is 2077 m, on Mt. Tardoki-Yani of the Sikhote-Alin range.

The climate of the region is submaritime, with warm Pacific air masses common in the summer but cold Siberian-Mongolian air masses prevailing in winter. The Sikhote-Alin range blocks the cold Siberian air from reaching the coast and causes a temperature difference of 10°C between the interior and the coast. In the summer the mountains prevent the warm interior air masses from reaching the coast. The mean temperature of the coldest month (January) ranges from −20°C in the interior to −10°C on the coast. In summer, the warmest month is August on the coast (monthly mean 20°C) and July in the interior (monthly mean 25°C). Mean annual temperature ranges from −0.4°C in the north to 5.2°C in the south. Annual precipitation ranges from 600 mm in the interior to 900 mm on the southeastern coast, with a profound orographic effect, particularly on the southeastern slopes.

Most of the region is covered by temperate forest. The main type on mesic sites at low elevations is a mixed forest dominated by *Pinus koraiensis* and a variety of broad-leaved tree species such as *Betula costata*, *Tilia amurensis*, *T. mandshurica*, *Fraxinus mandshurica*, *F. rhynchophylla*, *Kalopanax septemlobus*, *Quercus mongolica*, and *Q. dentata*. In the south *Abies holophylla* is also a component of this forest. *Picea jezoensis* var. *ajanensis* and *Abies nephrolepis* are frequently present, but their abundance decreases from north to south. On the Sikhote-Alin range, the vertical vegetation belts are: the mixed forest of broad-leaved trees and *Pinus koraiensis*, followed upward by *Picea-Abies* forests, *Betula ermanii* forests, *Pinus pumila* thickets, and alpine tundra. Azonal vegetation dominates in river valleys, including *Ulmus japonica-Fraxinus mandshurica* forests on well-developed valleys and *Salix rorida*, *Chosenia arbutifolia*, and *Populus maximowiczii* forests on sites with newer alluvial deposits. Major

vertical vegetation belts in this region are the mixed forest (broad-leaved plus Korean pine) occurring up to 400–500 m in the north and 800–900 m in the south, the dark conifer forest belt reaching 1500–1600 m, the *Betula ermanii* forest reaching 1600–1800 m, *Pinus pumila* thickets reaching 1900 m, above which is the alpine tundra belt.

The degree of endemism in vascular plants in this region is high. Endemic species include *Achyrophorus crepidioides*, *Aconitum desoulavyi*, *A. saxatile*, *A. sichotense*, *A. stoloniferum*, *Agrimonia gorovoii*, *A. granulosa*, *Agrostis sichotensis*, *Allium prokhanovii*, *A. spirale*, *Artemisia pannosa*, *Aruncus parvulus*, *Astragalus austrosachalinensis*, *Calamagrostis chassanensis*, *Caltha silvestris*, *Carex austroussuriensis*, *C. cenantha*, *C. charkeviczii*, *C. holotricha*, *C. mandshurica*, *C. pulchrifolia*, *Chrysosplenium schagae*, *Cirsium coryletorum*, *Clematis sichotealinensis*, *Cortusa discolor*, *Corydalis ussuriensis*, *Dendranthema coreanum*, *D. maximowiczii*, *Diarrhena koryoensis*, *Dimeria neglecta*, *Dontostemon intermedius*, *Draba cardaminiflora*, *Dracocephalum multicolor*, *Elsholtzia amurensis*, *Eriocaulon desulavii*, *Festuca amurensis*, *F. blepharogyna*, *Flueggea ussuriensis*, *Fraxinus densata*, *Girardinia septentrionalis*, *Gnaphalium rossicum*, *Hylotelephium eupatorioides*, *H. ussuriense*, *Iris vorobievii*, *Kitagawia eryngiifolia*, *Leontopodium palibinianum*, *Lepisorus kolesnikovii*, *Ligularia alticola*, *L. calthifolia*, *L. sichotensis*, *L. splendens*, *L. vorobievii*, *Lycopus alissoviae*, *L. charkeviczii*, *L. hirtellus*, *L. sichotensis*, *Megadenia speluncarum*, *Melica komarovii*, *Microbiota decussata*, *Mimulus stolonifer*, *Najas orientalis*, *Neottia ussuriensis*, *Orostachys vyschinii*, *Oxytropis charkeviczii*, *O. ruthenica*, *Paraixeris chelidoniifolia*, *Poa vorobievii*, *Polygonatum acuminatifolium*, *Polystichum subtripteron*, *Potentilla vorobievii*, *Pseudostellaria rigida*, *Rhododendron fauriei*, *Ribes fontaneum*, *Sanguisorba magnifica*, *Saussurea fulcrata*, *S. kolesnikovii*, *S. kurentzoviae*, *S. petiolata*, *S. porcellanea*, *S. sovietica*, *S. vyschinii*, *Saxifraga ascoldica*, *S. serotina*, *S. sichotensis*, *Scirpus oligosetus*, *Scutellaria ternejica*, *Silene obscura*, *S. olgae*, *Stachys komarovii*, *Teucrium maximowiczii*, *Thymus ternejicus*, *T. urussovii*, *T. ussuriensis*, *Trigonella schischkinii*, *Trillium rhombifolium*, *Veronica olgensis*, *Veronicastrum cerasifolium*, *Vicia subrotunda*, *Viola chassanica*, and *V. pacifica*.

3.6.12 Southern Sakhalin–Southern Kuril Archipelago (Region L, Fig. 4.1)

This region includes the southern parts of both Sakhalin (south of Schmidt's line) and the Kuril Archipelago. The southern Kurils include Simushir, Urup, and Iturup Islands, and northern Kunashir (north of Miyabe's line, as delineated in Tatewaki 1958). All these islands are mountainous. The highest elevations are 1325 m in southern Sakhalin (Mt. Vozvrashchenia) and 1819 m on Kunashir.

The climate of the region is suboceanic, with cold winters and cool summers, primarily influenced by air masses from the Pacific Ocean. Mean annual temperature ranges from 0 to 4.3°C. The mean temperature of the warmest month (August) ranges from 16 to 17.5°C, and that of the coldest month (January) from −17.7 at Poronaysk (Sakhalin) to −7.2°C at Kurilsk (southern Kurils). Annual precipitation is 600–1040 mm.

Boreal forests occur in this region, with a variety of temperate species. The zonal vegetation type is the *Picea-Abies* forest dominated by *Picea jezoensis* var. *ajanensis* and *Abies sachalinensis* (with abundance of the latter increasing from north to south). *Abies sachalinensis* forests, with dense understoreys of *Sasa senanensis* or *S. kurilensis*, occur where oceanic influence is strong. In the south, *Picea-Abies* stands usually contain temperate broad-leaved tree species such as *Quercus mongolica*, *Kalopanax septemlobus*, *Acer mono*, *Fraxinus mandshurica*, and *Juglans ailanthifolia*. Because elevations are relatively low, boreal dark-coniferous forests predomi-

nate throughout much of the region. The occurrence of subalpine and alpine vegetation on mountain tops results from edaphic factors (e.g. volcanic substrates) rather than from climatic conditions. Vertical vegetation zonation in this region is not distinguishable.

Endemic vascular species in this region include *Aconitum helenae*, *A. neosachalinense*, *Ajuga yezoensis*, *Anemone juzepczukii*, *Angelica sachalinensis*, *Arisaema sadoense*, *A. limosa*, *Astragalus kawakamii*, *Athyrium fauriei*, *Cardamine fauriei*, *Cardiocrinum cordatum*, *Carex neosachalinensis*, *Cirsium charkeviczii*, *Clinopodium kunashirense*, *Daphniphyllum humile*, *Dryopteris fragrantiformis*, *Erigeron schikotanensis*, *Eupatorium glehnii*, *Festuca probatoviae*, *Gentianella sugawarae*, *Ixeridium dentatum*, *I. kurilense*, *Juncus curvatus*, *Leontopodium kurilense*, *Ligustrum yezoense*, *Liparis sachalinensis*, *Lycopus kurilensis*, *Mimulus inflatus*, *Oxytropis bracteolata*, *O. itoana*, *O. kunashiriensis*, *O. todomoshiriensis*, *Papaver miyabeanum*, *Plagiogyria matsumurana*, *Primula matsumurae*, *Pulsatilla sachalinensis*, *P. taraoi*, *Rumex madajo*, *R. ochotskius*, *R. regelii*, *Sasa makinoi*, *S. niijimae*, *S. rivularis*, *S. shikotanensis*, *S. tyuhgokensis*, *Saussurea ainorum*, *S. kurilensis*, *S. nupuripoensis*, *Saxifraga yoshimurae*, *Skimmia repens*, *Sparganium kawakamii*, *Taraxacum miyakei*, *T. nairoense*, *T. neosachalinense*, *T. vulcanorum*, *Teucrium miquelianum*, *Thymus sachalinensis*, *Trillium apetalon*, *Veronica sachalinensis*, and *Veronicastrum borissovae*.

3.6.13 Daxingan-ling (Region M, Fig. 4.1)

This region is in northernmost China, north of about 49°21'N, mainly including the north-south-running Daxingan-ling mountain range (also known as the Greater Khinggan Mountains). Most of the mountains in this region range from 700 to 1100 m and have rounded or flat tops, gentle slopes, and wide valleys (Burger & Zhao 1988). Relative elevations (from base to tops of mountains) usually range from 100 to 400 m. The highest mountains (‘shan’ in Chinese) include Aokeliduo-shan (1530 m), Yingjili-shan (1460 m), Baikalu-shan (1410 m), Qingnian-shan (1350 m), and Xiaoniligulu-shan (1446 m).

Because this region is far from the sea and bordered by several large mountain systems to the east, the climate is typically continental, with long, dry, severely cold winters with little snow. Mean annual temperature ranges from −1.2 to −5.6°C. The mean temperature of the coldest month (January) ranges from −28 to −38°C, with a recorded extreme minimum of −52.3°C. The mean temperature of the warmest month (July) ranges from 15 to 20°C, and extremes can reach 35–39°C. The number of frost-free days per year is 90–110 (from late May to early September). Frost can occur as early as July. Annual precipitation is 360–500 mm. Although about 80% of the precipitation falls in the warm season, drought for plants can occur in May and June, due to the permafrost substrate, which impedes infiltration and causes surface runoff. In addition, the dry Mongolian winds result in evaporation rates that are 2 to 2.5 times as high as the annual precipitation of about 1000 mm (Chou 1991).

The zonal vegetation in the region is boreal (cool-temperate) *Larix gmelinii* forest, usually as pure stands. Mixed forests co-dominated by some of the following species can also be found in the region: *Pinus sylvestris* var. *mongolica*, *P. pumila*, *Picea koraiensis*, *P. jezoensis* var. *microsperma*, *Larix gmelinii*, *Betula pendula*, *B. davurica*, *B. ermanii*, *Quercus mongolica*, *Populus tremula* var. *davidiana*, *P. suaveolens*, *Chosenia arbutifolia*, and *Alnus hirsuta*. Because of the relatively low elevation range and gentle topography, vertical zonation is not always very striking. Three altitudinal forest belts can be distinguished: montane *Larix gmelinii* forest, upper-montane open *Pinus pumila-Larix gmelinii* forest, and subalpine dwarf *Pinus pumila* forest or thicket.

Endemic vascular species in this region include *Adenophora amurica*, *Carex borealis-*

hinganica, *C. rostellifera*, *C. yamatsudana*, *Delphinium hsinganense*, *Hippuris spiralis*, *Ribes liouanum*, *Salix humaensis*, *Sedum hsinganicum*, and *Stellaria hsinganensis*.

3.6.14 Xiaoxingan-ling–Changbai-shan (Region N, Fig. 4.1)

This region lies between 40°20' and 50°20'N and between 123°55' and 134°E, and has a complex topography. The major mountain ranges ('ling' in Chinese) include, from north to south, Xiaoxingan-ling (also known as the Lesser Khinggan Mountains), Wandashan, Zhangguangcai-ling (1760 m), Liaoye-ling, Changbai-shan (along the Chinese-Korean border), Longgang-shan, Hada-ling, and Qian-shan. Most ranges do not exceed 1300 m in elevation. The highest peak is Baiyunfeng (2691 m), on the Chinese side of Changbai-shan.

The climate is milder and moister than in the deciduous coniferous forest region to the north. Mean annual temperature at low elevations (below 600 m) is 0.5 to 5.5°C. The mean temperature of the coldest month (January) ranges from −16 to −25°C, and that of the warmest month (July) from 20 to 26°C. Annual precipitation ranges from 500 to 800 (up to 1000) mm, 70–80% of which falls from June to August.

Mixed forests of evergreen conifers and deciduous broad-leaved trees predominate at elevations below 700 m in the north and 1160 m in the south. *Pinus koraiensis* is a characteristic tree species, but several other evergreen coniferous tree species can also be found in this forest type: *Abies holophylla*, *A. nephrolepis*, *Picea jezoensis*, *P. koraiensis*, *Taxus cuspidata*, and *Thuja koraiensis*. Among the major deciduous broad-leaved tree species are *Acer mandshuricum*, *A. mono*, *A. pseudosieboldianum*, *A. tegmentosum*, *A. triflorum*, *Phellodendron amurense*, *Fraxinus mandshurica*, *Maackia amurensis*, *Juglans mandshurica*, *Populus maximowiczii*, *P. koreana*, and *Tilia amurensis*. Because of the wide span in latitude (more than 10°), this region has marked differences in precipitation, temperature, and hence species composition from north to south. Two sub-regions can be recognized: a) mixed forest (evergreen conifers plus deciduous broad-leaved trees) in the north and b) more diverse mixed forest (called 'nearly warm-temperate' in Chinese terminology) in the south (Chou & Liu 1995). Four vertical vegetation belts can be identified: 1) montane mixed forest (*Pinus koraiensis* plus deciduous broad-leaved trees), 2) upper-montane *Pinus koraiensis-Picea-Abies* forest, 3) subalpine (dwarf) *Betula ermanii* forest, and 4) alpine tundra.

Endemic vascular species in this region include *Aconitum dunhuaense*, *A. fusungense*, *Artemisia brachyphylla*, *Astilboides tabularis*, *Athyrium dailingense*, *Cardamine baishanensis*, *Carex kirinensis*, *C. pseudobiwensis*, *C. pseudolongerostrata*, *Cerastium baischanense*, *Diplandrorchis sinica*, *Dysophylla fauriei*, *Forsythia mandshurica*, *Gentiana uchiyamai*, *Geranium baishanense*, *Huperzia lucidula*, *Iris maackii*, *Ixeris chelidonifolia*, *Ligularia biceps*, *Lilium megalanthum*, *Malus komarovii*, *Pinus sylvestriformis*, *Plantago huadianica*, *Poa acmocalyx*, *Polygonum kirinense*, *P. pronum*, *Prenanthes blinii*, *Pyrola macrocalyx*, *P. tschanbaischanica*, *Rhododendron confertissimum*, *Salix polyadenia*, *Saussurea sclerolepis*, *S. tenerifolia*, *Scrophularia mandshurica*, *Serratula hayatae*, *Sparganium multipocatum*, *S. tenuicaule*, *Swertia manshurica*, *Thuja koraiensis*, *Trapa arcuata*, *Trollius macropetalus*, *Viola lii*, and *V. savatieri*.

3.6.15 Liaoning (Region O, Fig. 4.1)

This region roughly coincides with Liaoning Province of China. Only a few mountains exceed 1000 m in elevation, and the middle of the region is mainly a plain, much of which is below 400 m. To both the west and east, elevations generally range from 300 to 500 m. The Buyun-shan (1132 m) and Wanghai-shan (886 m) are among the highest mountains in the region.

The region has a monsoonal climate with hot, rainy summers and cold, dry winters. Mean annual temperature ranges from 6 to 10°C, but much of the region is within the range of 7 to 8°C. Mean July temperature is 22 to 26°C, and mean January temperature ranges from −5 to −15°C. Nearer the Pacific Ocean, to the east, annual precipitation reaches 1000 to 1200 mm; in the west it is only about 500–600 mm.

The zonal vegetation is deciduous broad-leaved forest, with more than 20 species of deciduous broad-leaved trees commonly occurring in the region, many of them as dominant species in forest communities. Some are also dominants in areas to the north, e.g. *Quercus acutissima*, *Q. aliena*, *Q. dentata*, *Q. liaotungensis*, *Q. mongolica*, and *Q. variabilis*. In addition, many subtropical trees or shrubs extend northward into this region, e.g. *Toxicodendron vernicifluum*, *Rhus javanica*, *Kalopanax septemlobus*, *Lindera obtusiloba*, *Alangium platanifolium*, *Symplocos paniculata*, *Styrax obassia*, and *Magnolia sieboldii*. Many woody vines, such as *Schisandra chinensis*, *Actinidia arguta*, *A. kolomikta*, *A. polygama*, *Vitis amurensis*, *Pueraria montana* var. *lobata*, *Aristolochia manchuriensis*, and *Tripterygium regelii*, are also common components in deciduous broad-leaved forests. Furthermore, some of the common trees or shrubs of the mixed-forest region to the north are also present in this region, e.g. *Quercus mongolica*, *Acer mono*, *Maackia amurensis*, *Phellodendron amurense*, *Juglans mandshurica*, *Tilia amurensis*, *T. mandshurica*, *Eleutherococcus senticocus*, and *Corylus mandshurica*. Where soils are shallow or infertile, pines (*Pinus tabulaeformis* and *P. densiflora*) are usually mixed with deciduous broad-leaved trees or become dominants. Elevations in the region are not high enough for vertical vegetation zonation.

Endemic vascular species in this region include *Aconitum fauriei*, *Artemisia chienshanica*, *Betula ceratoptera*, *Brachypodium manshuricum*, *Caragana litwinowii*, *Diplazium taquetii*, *Iris kobayashii*, *I. minutoaurea*, *Ligusticum tenuissimum*, *Limonium franchetii*, *Phaseolus demissus*, *Phragmites hirsuta*, *Phymatopteris hastata*, *Pyrus corymbifera*, *Rorippa liaotungensis*, *Rosa baiyushanensis*, *Salix donggouxianica*, *Scutellaria planipes*, *Spiraea nishimurae*, *Suaeda liaotungensis*, *Taraxacum antungense*, *Viola liaosiensis*, and *V. rhodosepala*.

3.6.16 Eastern Neimonggu (Region P, Fig. 4.1)

This region (also called eastern Inner Mongolia) includes the Northeast China ('Dongbei' in Chinese) Plain, the Neimonggu Plateau, and southern Daxingan-ling. The Neimonggu Plateau has elevations usually between 600 and 800 (1000) m. The central and eastern part of the region is occupied by plains with main elevations at 100–180 m. This region is surrounded, however, by high mountain ranges.

The region has a typical continental climate, with mean annual temperature between 1 and 2°C. The mean temperature of the coldest month (January) ranges from −18 to −28°C, and that of the warmest month (July or August) from 18 to 21°C. The number of frost-free days is 120–150. Annual precipitation is 250–500 mm, decreasing from east to west. Much of the precipitation falls in July and August. Due to the strong dry Mongolian wind, the ratio of annual evaporation to annual precipitation is 2 to 5 and can reach 10 in the west, indicating a high degree of aridity.

The zonal vegetation is temperate steppe. Dominant species include *Stipa grandis*, *S. krylovii*, *Cleistogenes squarrosa*, *Agropyron cristatum*, *Koeleria cristata*, *Artemisia frigida*, *Festuca ovina*, *Thymus serpyllum*, *Caragana microphylla*, *C. pygmaea*, and *Iris tenuifolia*. Other major species in temperate steppe communities include *Bupleurum scorzonerifolium*, *Astragalus adsurgens*, *A. melilotoides* var. *tenuis*, *Artemisia laciniata*, *Scutellaria baicalensis*, *Leontopodium leontopodioides*, *Euphorbia fischeriana*, *Stellera chamaejasme*, *Sanguisorba officinalis*, *Thalictrum squarro-*

sum, *Oxytropis myriophylla*, *Glycyrrhiza uralensis*, *Leymus chinensis*, and *Spodiopogon sibiricus*. Much of the transition from this region eastward is occupied by temperate forest-steppe.

Endemic vascular species in this region include *Adenophora borealis*, *A. micrantha*, *Artemisia zhaodongensis*, *Astragalus hulunensis*, *Corispermum dilutum*, *C. flexuosum*, *C. retortum*, *Draba multiceps*, *Ligularia ovato-oblonga*, *Limnophila borealis*, *Potentilla pannifolia*, and *Spiraea hailarensis*.

3.6.17 North Korea (Region Q, Fig. 4.1)

This region, the northern half of the Korean Peninsula, is separated from Northeast China by the Yalu (Amnok) River and from Russia by the Tuman River. It is open to the Sea of Japan on the east and to the Yellow Sea on the west. The region is generally mountainous, with high, steep mountains located mainly in the northeast. In contrast, much of the northwest and southwest is occupied by low mountains (usually with gentle slopes) or plains, e.g. the Pyongyang Plain and Jaeryong Plain. There are two major mountain systems ('san' in Korean) in the region: one generally runs northwest-southeast and includes Macheonryong-san, Nangrim-san, and Taebaek-san; the other runs more or less north-south and includes Paektu-san (known as Changbai-shan in China), Kangnam-san, Jeokyooryong-san, Myohyang-san, Eonjin-san, Meolak-san, and Mashikryong-san. Among major mountains in this region are Paektu-san (2744 m, the highest peak in the Korean Peninsula), Kwanmobong-san (2540 m), Buksubaek-san (2450 m), Nampotae-san (2434 m), Durobong-san (2400 m), Yeonhwa-san (2250 m), Wegalbong-san (2210 m), Namunryong-san (2200 m), and Kumgang-san (1638 m).

The climate has both strong continental and oceanic influences. Continental high-pressure air masses that develop over Siberia bring cold, dry air into the region in winter. During summer, the monsoonal Pacific rain front brings abundant moisture to the region, producing much precipitation. Mean annual temperature is 3.9°C at Junggangjin in the north and 9.4°C at Pyongyang in the south. The mean temperature of the coldest month ranges from −1.8 to −20.8°C, and that of the warmest month from 17.8 to 26.1°C. Annual precipitation ranges from 509 to 1323 mm at low elevations.

Cool-temperate and boreal forests cover most of the region. Coniferous forests prevail in the northeast, with the following major coniferous tree species: *Larix olgensis*, *Abies nephrolepis*, *A. holophylla*, *Picea jezoensis*, *P. koraiensis*, and *P. koraiensis* var. *pungsanensis*. *Quercus mongolica* and *Pinus densiflora* occur in various types of forest. In addition, many other broad-leaved tree species occur in various forest types, particularly in montane areas, e.g. *Quercus dentata*, *Ulmus* spp. (e.g. *U. pumila*), *Acer mandshuricum*, *A. mono*, *Betula costata*, *B. schmidtii*, *B. pendula*, *Celtis bungeana*, *Chosenia arbutifolia*, *Corylus mandshurica*, *Populus tremula* var. *davidiana*, *P. maximowiczii*, *Salix koreensis*, *S. cardiophylla*, *S. rorida*, and *Tilia amurensis*. Some tree species are commonly found on moist sites, such as *Acer pseudosieboldianum*, *A. mono*, *A. palmatum*, *A. triflorum*, *A. tegmentosum*, *A. ukurunduense*, *Carpinus laxiflora*, and *Fraxinus rhynchophylla*. *Betula fruticosa*, *Spiraea salicifolia*, and *Salix myrtilloides* var. *mandshurica* are among common species on wet sites. In the southernmost part of the region, *Zelkova serrata* and several *Quercus* species occur in forest stands, such as *Q. serrata*, *Q. variabilis*, and *Q. acutissima*. Shrubs frequently found in this southernmost area include *Callicarpa dichotoma*, *Codonopsis lanceolata*, *Rhus javanica*, *Toxicodendron vernicifluum* (*Rhus verniciflua*), and *Viburnum carlesii*.

Endemic vascular species in this region include *Alnus vermicularis*, *Arabis ligulifolia*, *Calamagrostis paishanensis*, *C. subacrochaeta*, *Callianthemum insigne*, *Carex humbertiana*, *Celtis cordifolia*, *Clematis subtriternata*, *Coeloglossum coreanum*, *Erysimum auranthiacum*, *Euphrasia coreanalpina*, *E.*

retrotricha, *Hanabusaya latisepala*, *Lamium cuspidatum*, *Liparis koreana*, *Melandrium umbellatum*, *Oxytropis koreana*, *Papaver coreanum*, *Pedicularis lunaris*, *P. nigrescens*, *Pentactina rupicola*, *Pilea oligantha*, *Polygonum globispica*, *Pulsatilla nivalis*, *Rhamnus shozyoensis*, *Rheum coreanum*, *Rubia pubescens*, *Salix bicarpa*, *S. sericeo-cinerea*, *Sasa coreana*, *Saussurea rectinervis*, *S. rorinsanensis*, *S. stenolepis*, *Saxifraga furumii*, *Scutellaria asperiflora*, *Spiraea pseudo-crenata*, *Thalictrum osmorhizoides*, *T. spirostigmum*, *Tilia semicostata*, and *Viola koraiensis*.

3.6.18 Hokkaido (Region R, Fig. 4.1)

Hokkaido is the northernmost main island of Japan and lies between 41°24' and 45°31'N. It is a mountainous island. In the southwest the major mountains include Mt. Makkarinupuri (1895 m), Mt. Niseko-annupuri (1309 m), and Mt. Eniwa (1320 m). The central mountains form the backbone of Hokkaido and exceed 1500 m, including the Hidaka and Taisetsu ranges. Elevations generally range from 1600 to 1800 m in the Hidaka range, with Mt. Poroshiri as the highest peak (2052 m). The Taisetsu mountains include many high peaks, such as Mt. Asahi (2290 m, the highest peak in Hokkaido) and Mt. Tokachi (2077 m). In general, elevation increases from north to south. The island also has three major lowlands: the Ishikari, Tokachi, and Kushiro Plains (Kojima 1979).

The climate is essentially moist continental, with cold winters and warm summers, but with some degree of oceanic influence. In general, the climate is cool and dry in the east and relatively mild and humid in the west. High-pressure systems invading frequently from northern Eurasia bring cold winters with at least three months of mean temperature below 0°C. Interior Hokkaido, where continentality is pronounced, can have extreme minima of −40°C. At low elevations there are 4–6 months with mean monthly temperature above 10°C (Kojima 1979). Annual precipitation ranges from 700 to 2200 mm. September usually is the wettest month.

Cool-temperate forests appear at elevations between 500 and 1500 m (Ching 1991) and broad-leaved deciduous forests prevail at low elevations (Kojima 1979). Major deciduous trees in this region belong to the genera *Acer*, *Alnus*, *Betula*, *Fraxinus*, *Juglans*, *Phellodendron*, *Quercus*, *Tilia*, and *Ulmus*. *Fagus crenata* forests occur on the southern peninsula, starting at the sea level and reaching approximately 200 m in elevation. *Quercus mongolica* forests develop best on lowlands. Coniferous forests are found at mid to high elevations, with *Abies sachalinensis*, *Picea jezoensis*, and *P. glehnii* among the major components. Vertical vegetation zonation is apparent on Hokkaido and is well represented in the Taisetsu mountains (from low to high elevations): mixed forest (broad-leaved plus coniferous trees), coniferous forest, *Betula ermanii* forest, and *Pinus pumila* scrub.

Endemic vascular species in this region include *Aconitum ito-seiyanum*, *A. yamazakii*, *A. yesoense*, *A. yuparense*, *Angelica stenoloba*, *Astilbe platyphylla*, *Astragalus yamamotoi*, *Betula apoiensis*, *Botrychium microphyllum*, *Callianthemum miyabeanum*, *Carex fedia*, *C. mertensii*, *C. michauxiana*, *Carpesium matsuei*, *Chrysanthemum weyrichii*, *Cirsium apoiense*, *Corydalis curvicalcarata*, *Crepis gymnopus*, *Deschampsia atropurpurea*, *Draba igarashii*, *Elymus yubaridakensis*, *Eriocaulon glaberrimum*, *E. kusiroense*, *E. pallescens*, *E. perplexum*, *Gentianella yuparensis*, *Hierochloë pluriflora*, *Hosta atropurpurea*, *Hylotelephium cauticolum*, *Hypericum samaniense*, *H. yamamotoi*, *H. yojiroanum*, *Hypochaeris crepidioides*, *Juncus mertensianus*, *J. satakei*, *J. tokubuchii*, *Lagotis stelleri*, *Lonicera alpigena*, *Mitrasacme alsinoides*, *Najas yezoensis*, *Oxytropis kudoana*, *O. rishiriensis*, *O. shokanbetsuensis*, *Papaver fauriei*, *Polemonium yezoense*, *Polygonum tatewakianum*, *Primula hidakana*, *P. sorachiana*, *P. takedana*, *P. yuparensis*, *Rhamnus ishidae*, *Salix paludicola*, *S. yezoalpina*, *Sanguisorba japonensis*, *Saussurea chionophylla*, *S.*

yanagisawae, *Saxifraga nishidae*, *Scorzonera rebunensis*, *Silene hidaka-alpina*, *Stellaria pterosperma*, *Taraxacum yuparense*, *Thalictrum integrilobum*, *Thlaspi japonicum*, *Viola alliariaefolia*, *V. kitamiana*, *V. rostrata*, and *V. yubariana*.

3.7 Distributions of major tree species in Northeast Asia

There are about 200 tree species native to Northeast Asia, many of which are restricted to the southern area. Geographic distributions for selected 53 major tree species in Northeast Asia (Table 4.8) are shown in Fig. 4.8.

4. SUMMARY

The flora of Northeast Asia consists of 971 genera and 4953 species of native vascular plants. Pteridophytes, gymnosperms, and angiosperms make up 5.7, 1.1, and 93.2%, respectively, at the genus level, and 4.4, 0.7, and 94.9% at the species level. The 971 genera of vascular plants were grouped into the following fourteen phytogeographic elements: cosmopolitan (119 genera), pantropical (89), amphi-Pacific tropical (17), paleotropical (32), tropical Asia–tropical Australia (12), tropical Asia–tropical Africa (10), tropical Asia (12), holarctic (295), eastern Asia–North America (80), temperate Eurasia (118), temperate Asia (36), Mediterranean, western Asia to central Asia (20), central Asia (13), and eastern Asia (118). Seven genera and over 900 species of vascular plants are endemic to Northeast Asia.

Northeast Asia shares 39% of its species with eastern Siberia-Mongolia, 24% with Europe, 16.2% with western North America, and 12.4% with eastern North America. To determine species richness and floristic relationships at smaller spatial scales within Northeast Asia, the area was divided into eighteen regions.

Table 4.8. Major tree species in the forest vegetation of Northeast Asia (see Fig. 4.8 for geographic distributions of the tree species in the study area).

1. *Abies holophylla*
2. *Abies nephrolepis*
3. *Abies sachalinensis*
4. *Larix gmelinii*
5. *Larix olgensis*
6. *Picea glehnii*
7. *Picea jezoensis*
8. *Picea koraiensis*
9. *Pinus densiflora*
10. *Pinus koraiensis*
11. *Pinus pumila*
12. *Pinus sylvestris*
13. *Pinus tabulaeformis*
14. *Platycladus orientalis*
15. *Thuja koraiensis*
16. *Acer mono*
17. *Alnus hirsuta*
18. *Betula chinensis*
19. *Betula costata*
20. *Betula davurica*
21. *Betula ermanii*
22. *Betula platyphylla*
23. *Carpinus cordata*
24. *Carpinus laxiflora*
25. *Carpinus turczaninovii*
26. *Celtis bungeana*
27. *Chosenia arbutifolia*
28. *Fraxinus mandshurica*
29. *Fraxinus rhynchophylla*
30. *Juglans mandshurica*
31. *Kalopanax septemlobus*
32. *Koelreuteria paniculata*
33. *Phellodendron amurense*
34. *Populus koreana*
35. *Populus maximowiczii*
36. *Populus pseudo-simonii*
37. *Populus simonii*
38. *Populus suaveolens*
39. *Populus tremula*
40. *Prunus sibirica*
41. *Quercus acutissima*
42. *Quercus aliena*
43. *Quercus dentata*
44. *Quercus liaotungensis*
45. *Quercus mongolica*
46. *Quercus variabilis*
47. *Salix udensis*
48. *Tilia amurensis*
49. *Tilia japonica*
50. *Tilia mandshurica*
51. *Ulmus japonica*
52. *Ulmus laciniata*
53. *Ulmus macrocarpa*

About 45% of the 4953 species found in Northeast Asia are restricted to only one or two of the eighteen regions, and less than 1% are distributed in all eighteen regions. Species richness markedly decreases, as expected, along a latitudinal gradient from south to north. An area in the south can have 2–3 times as many species as one with the same size in

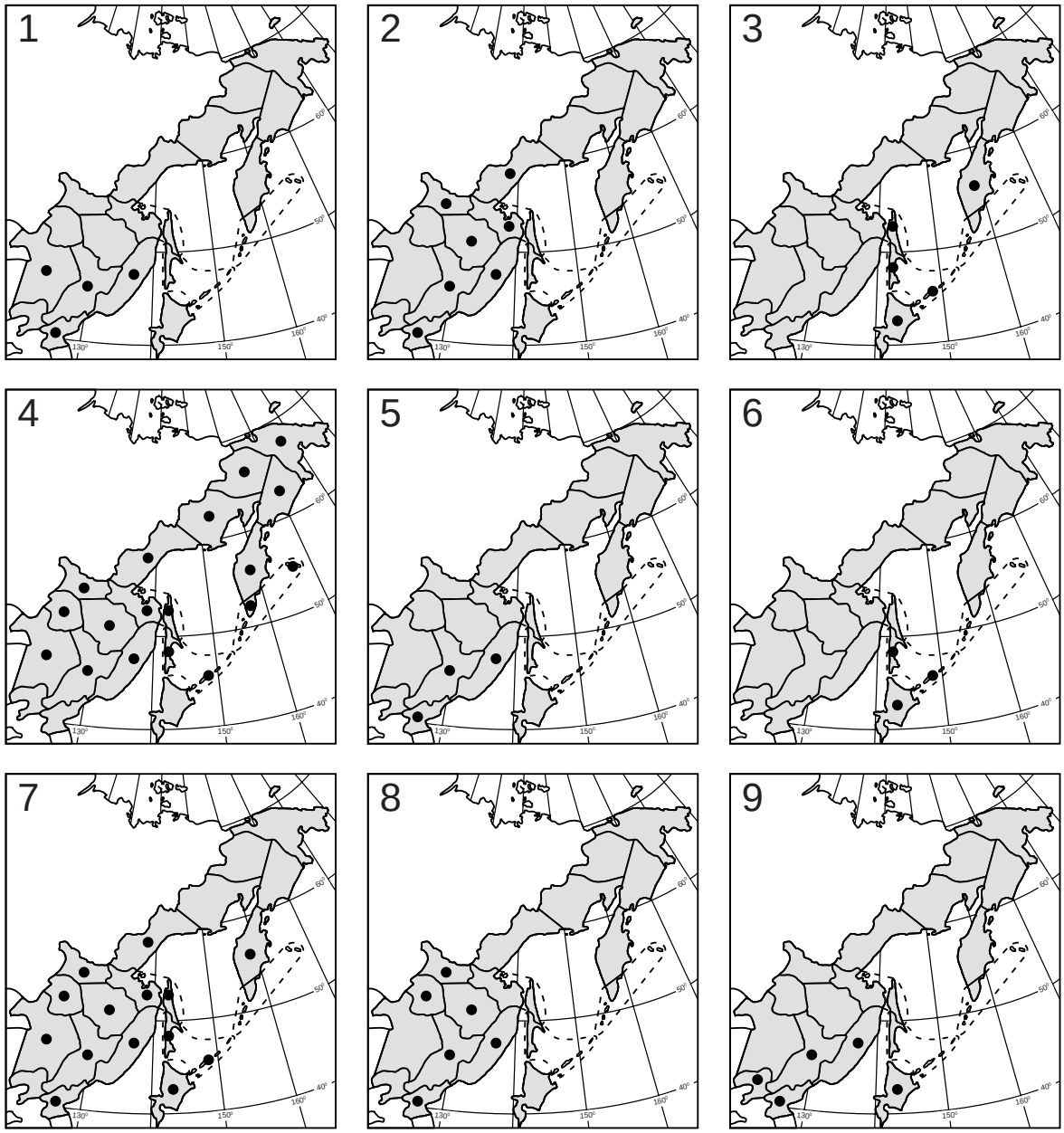

Figure 4.8a. Geographic distributions of 53 major tree species in Northeast Asia: 1 = *Abies holophylla*; 2 = *Abies nephrolepis* (*A. gracilis*); 3 = *Abies sachalinensis* (*A. wilsonii*); 4 = *Larix gmelinii* (*L. dahurica*, *L. pumila*, *L. amurensis*); 5 = *Larix olgensis* (*L. olgensis* var. *changpaiensis*, *L. olgensis* var. *heilingensis*, *L. olgensis* var. *koreana*); 6 = *Picea glehnii*; 7 = *Picea jezoensis*, including *P. jezoensis* var. *ajanensis* (*P. komarovii*, *P. kamtschatkensis*, *P. microsperma*); 8 = *Picea koraiensis* (*P. manshurica*, *P. intercedens*, *P. intercedens* var. *glabra*, *P. tonaiensis*); 9 = *Pinus densiflora* (*P. funebris*), including *P. densiflora* var. *ussuriensis*.

the north. Within Northeast Asia, the northernmost region (Chukotka) located in the Arctic shares 64% of its genera and 9% of its species with the southernmost region (Liaoning) located in warm temperate deciduous broad-leaved forest zone.

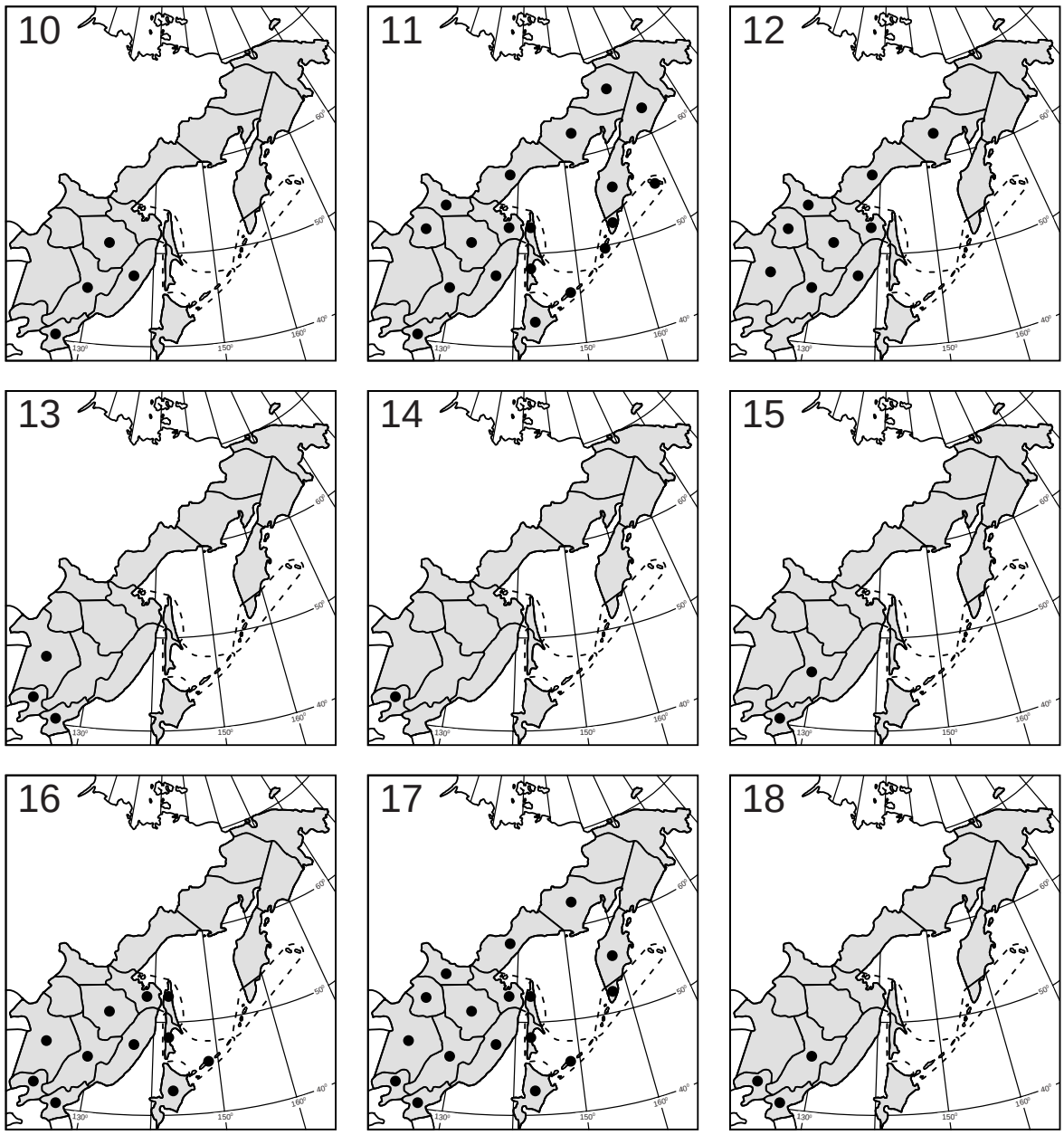

Figure 4.8b. Geographic distributions of major tree species in Northeast Asia: 10 = *Pinus koraiensis*; 11 = *Pinus pumila*; 12 = *Pinus sylvestris* (*P. krylovii*, *P. fominii*), including *P. sylvestris* var. *mongolica* and *P. sylvestris* var. *sylvestriformis*; 13 = *Pinus tabulaeformis*; 14 = *Platycladus orientalis* (*Thuja orientalis*); 15 = *Thuja koraiensis*; 16 = *Acer mono*; 17 = *Alnus hirsuta* (*A. sibirica*, *A. tinctoria*); 18 = *Betula chinensis.*

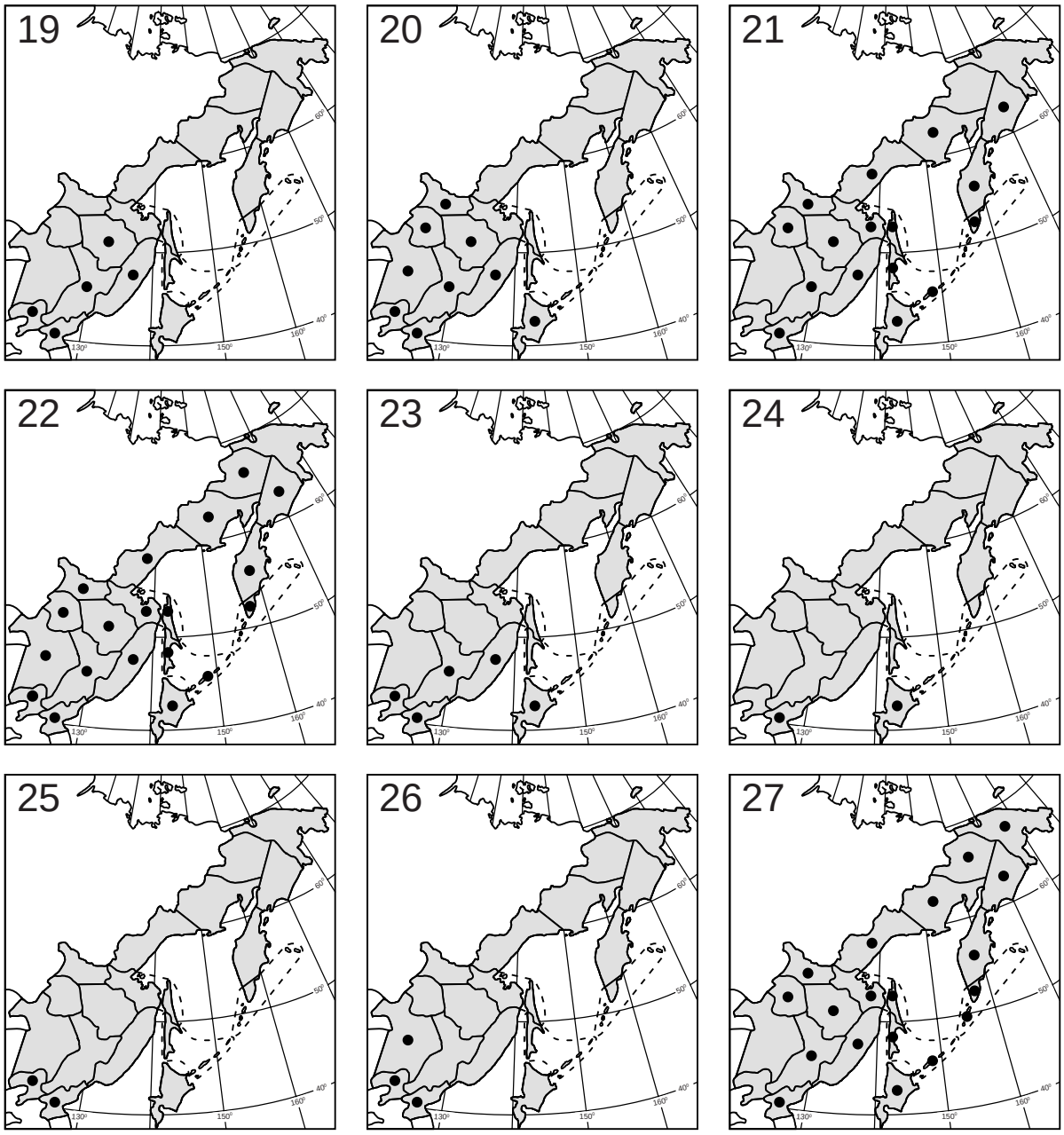

Figure 4.8c. Geographic distributions of major tree species in Northeast Asia: 19 = *Betula costata*; 20 = *Betula davurica*; 21 = *Betula ermanii* (B. *paraermanii*, *B. komarovii*, *B. ulmifolia*); 22 = *Betula platyphylla* (*B. ajanensis*, *B. cajanderi*, *B. demetrii*, *B. grandifolia*, *B. kamtschatica*, *B. mandshurica*, *B. platyphylla* ssp. *minutifolia*, *B. platyphylla* var. *cuneifolia*, *B. platyphylla* var. *japonica*, *B. platyphylla* var. *pluricostata*, *B. tauschii*); 23 = *Carpinus cordata*; 24 = *Carpinus laxiflora*; 25 = *Carpinus turczaninovii*; 26 = *Celtis bungeana*; 27 = *Chosenia arbutifolia* (*C. bracteosa*, *C. macrolepis*).

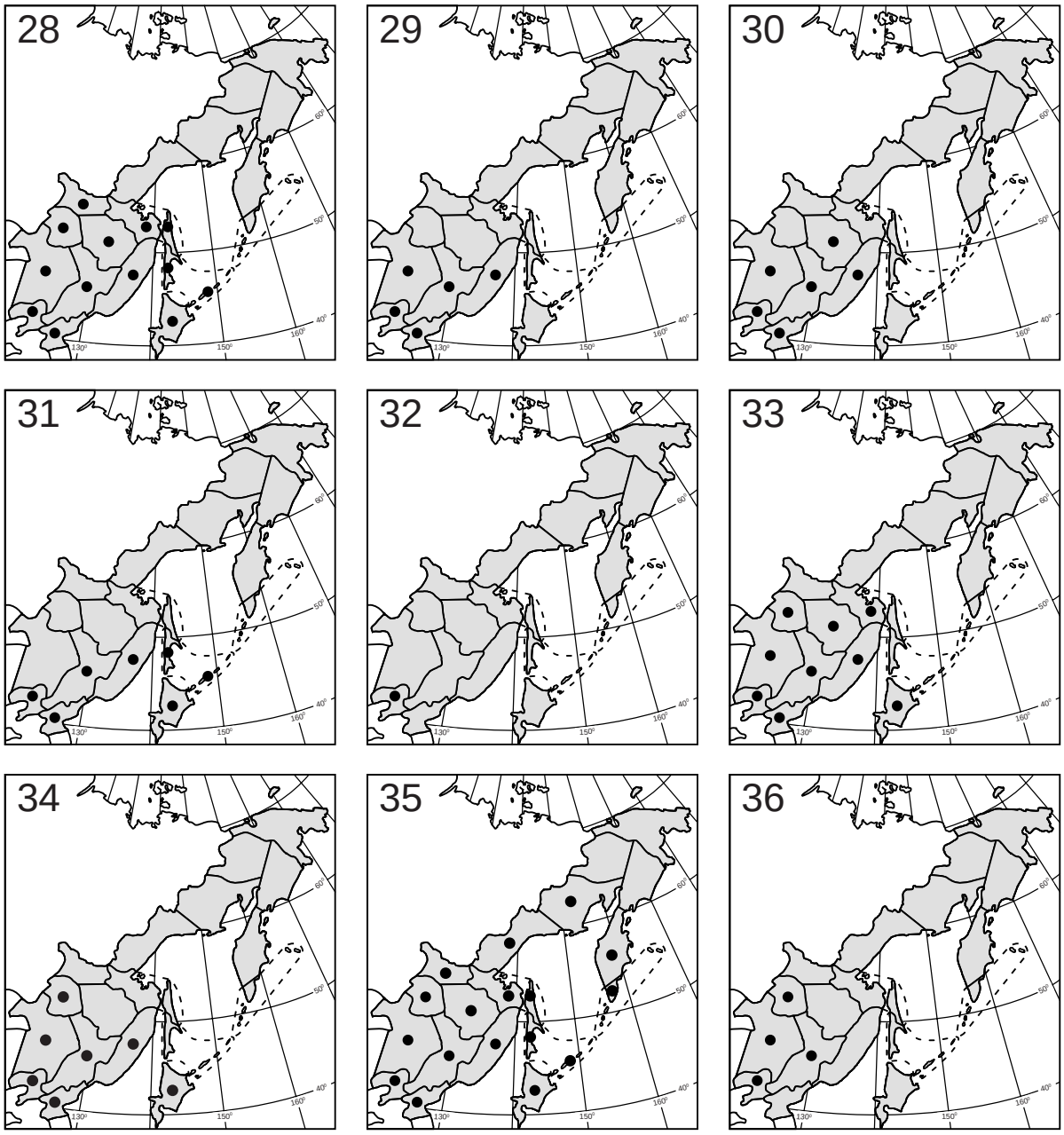

Figure 4.8d. Geographic distributions of major tree species in Northeast Asia: 28 = *Fraxinus mandshurica*; 29 = *Fraxinus rhynchophylla*; 30 = *Juglans mandshurica*; 31 = *Kalopanax septemlobus* (*K. pictus*, *K. pictus* var. *lutchuensis*); 32 = *Koelreuteria paniculata*; 33 = *Phellodendron amurense*; 34 = *Populus koreana*; 35 = *Populus maximowiczii* (*P. komarovii*, *P. ussuriensis*); 36 = *Populus pseudo-simonii.*

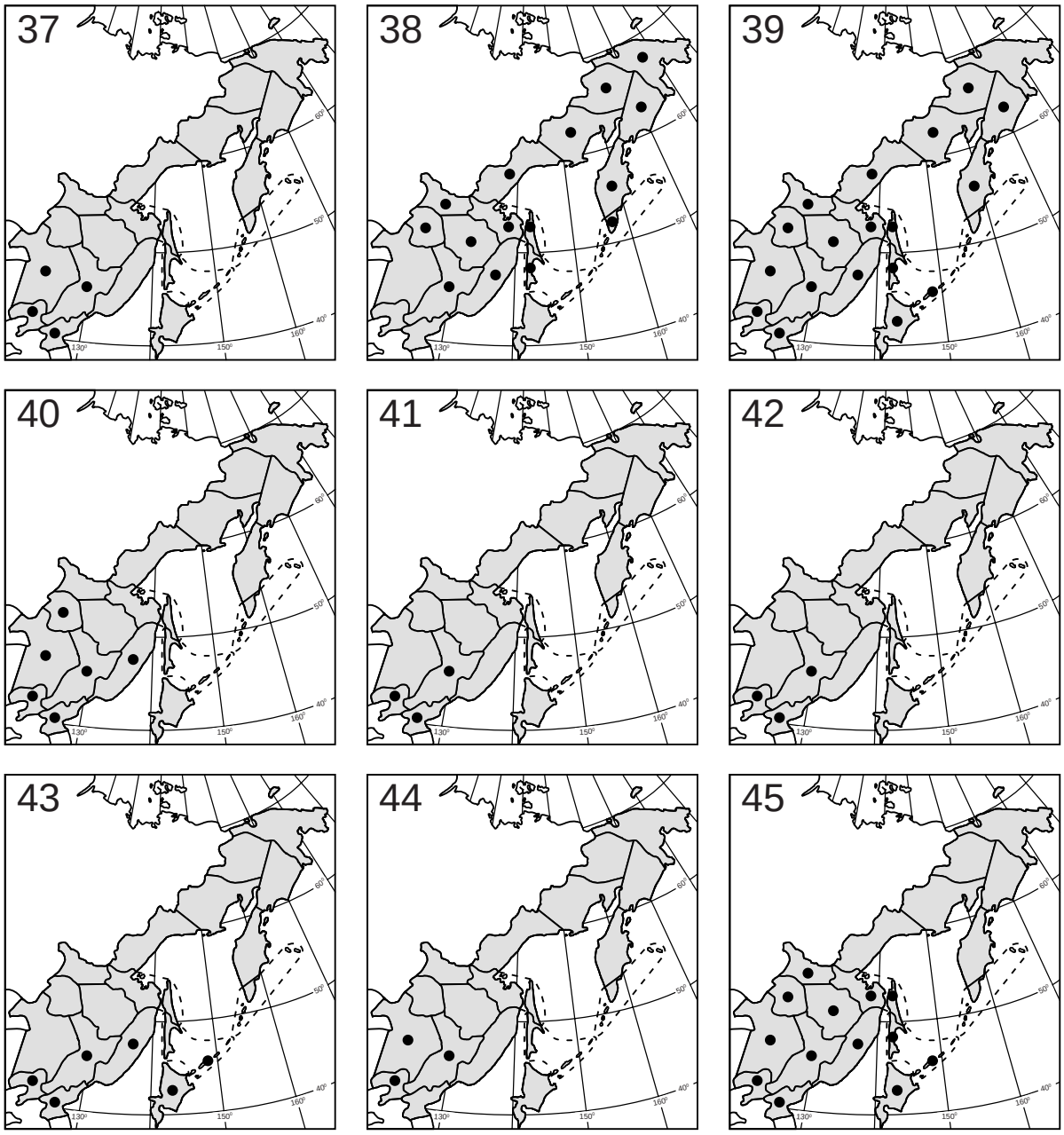

Figure 4.8e. Geographic distributions of major tree species in Northeast Asia: 37 = *Populus simonii*; 38 = *Populus suaveolens* (*P. baicalensis*); 39 = *Populus tremula* (*P. pseudotremula*), including *P. tremula* var. *davidiana* (*P. davidiana*, *P. jezoensis*); 40 = *Prunus sibirica*; 41 = *Quercus acutissima*; 42 = *Quercus aliena*; 43 = *Quercus dentata*; 44 = *Quercus liaotungensis*; and 45 = *Quercus mongolica*, including *Q. mongolica* var. *grosseserrata* (*Q. crispula*).

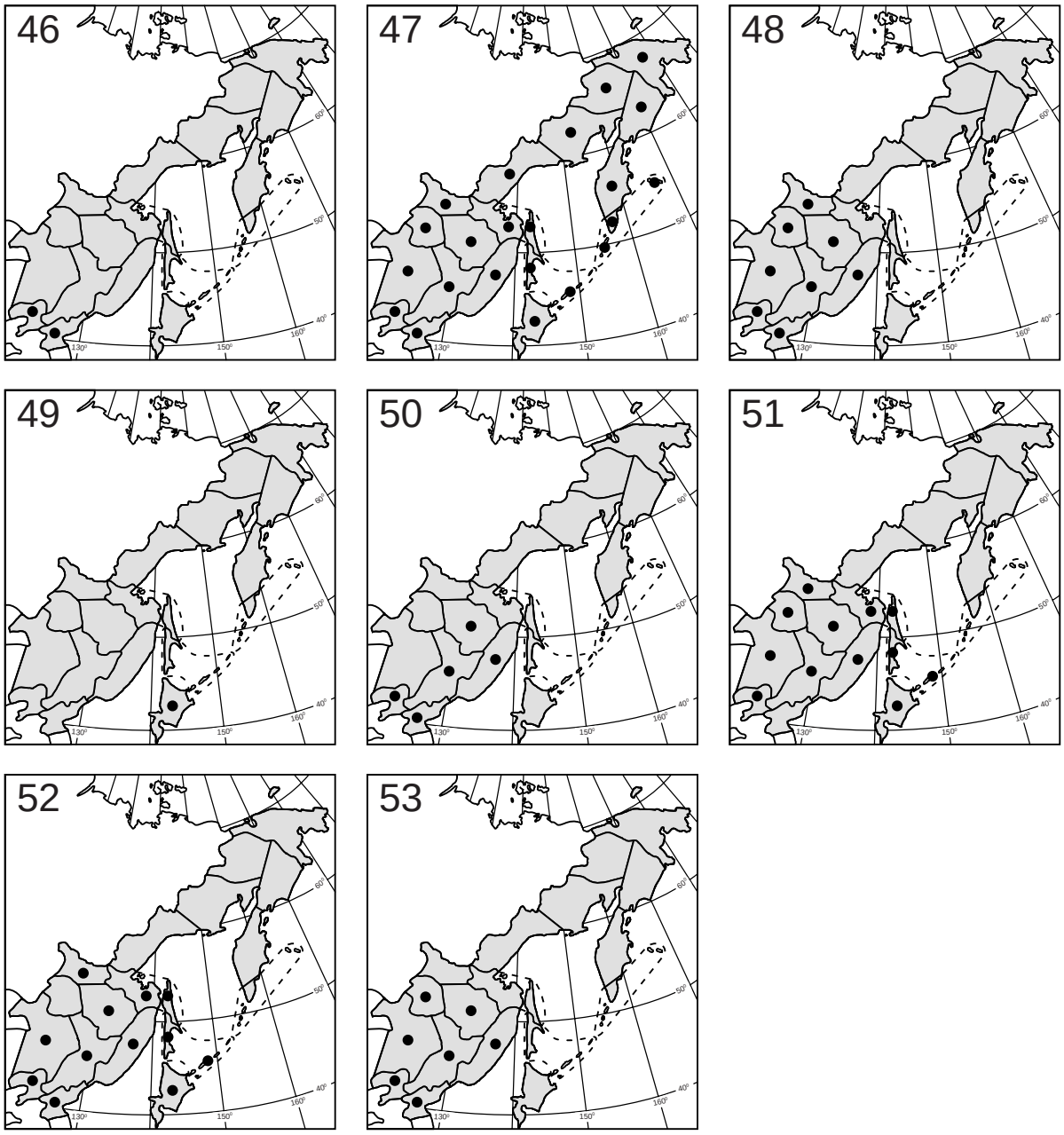

Figure 4.8f. Geographic distributions of major tree species in Northeast Asia: 46 = *Quercus variabilis*; 47 = *Salix udensis* (*S. mezereoides*, *S. oblongifolia*, *S. opaca*, *S. paramushirensis*, *S. sachalinensis*, *S. siuzevii*); 48 = *Tilia amurensis* (*T. divaricata*, *T. komarovii*, *T. koreana*, *T. mongolica* var. *austroussuriensis*), including *T. amurensis* var. *taquetii* (*T. amurensis* var. *rufa*); 49 = *Tilia japonica*; 50 = *Tilia mandshurica* (*T. pekinensis*); 51 = *Ulmus japonica* (*U. propinqua*); 52 = *Ulmus laciniata*; 53 = *Ulmus macrocarpa*.

5. ACKNOWLEDGMENT

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