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MOSS DIVERSITY IN THE WESTERN AND NORTHERN PALEARCTIC
РАЗНООБРАЗИЕ МХОВ В ЗАПАДНОЙ И СЕВЕРНОЙ ПАЛЕАРКТИКЕ

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Abstract

The moss flora of the Western and Northern Palearctic includes 1667 species of 300 genera and 67 families. The south-western half of Europe has the highest species diversity in this area, and also more rich in endemics. Endemic species of the Western and Northern Palearctic are 532, or 32.5% of total moss flora; this value seems inflated by insufficiently known taxa, so the real species endemism can be evaluated at about 20%. About a third of endemics have a relatively wide distribution. Generic endemism is low, about 10-16 genera, all monotypic and a third of them known from the type locality only. One family, Cinclidotaceae, with 1 genus and 8 species is subendemic for the Western and Northern Palearctic. Pottiaceae is the largest family in this area; they include ca. 1/5 of its species diversity.

Резюме

Флора мхов Западной и Северной Палеарктики насчитывает 1667 видов из 300 родов, 67 семейств. Юго-западная половина Европы имеет наибольшее видовое разнообразие, а также наиболее богата эндемичными видами. Эндемичных видов мхов в Западной и Северной Палеарктики 532, или 32.5% от всей флоры мхов; это значение завышено из-за включения в рассмотрение отдельных слабоизученных видов; реальный видовой эндемизм может быть оценен около 20%. Около трети эндемиков имеют относительно широкое распространение. Родовых эндемиков от 10 до 16, в зависимости от признания отдельных родов; все они монотипные, около трети известны только из типовых местонахождений. Одно семейство, Cinclidotaceae (1 род, 8 видов) – субэндемик Западной и Северной Палеарктики. Pottiaceae – крупнейшее семейство данного региона, включающее около 1/5 всех видов.

INTRODUCTION AND THE AREA STUDIED

The main pattern of phytogeographical division of the world appeared first in the publications on vascular plants. Theodor Herzog who first provided a worldwide account on the distribution of bryophytes in his famous "Die Moose Geographie" (Herzog, 1926) used the same phytogeographical entities as for the vascular plants. Subsequent studies of moss distribution mostly supported the usefulness for bryogeography of the delimiting boundaries proposed by the phanerogamists.

The present study uses nearly the same definition of Palearctic (part of Holarctic within the Old World) which is accepted by the vascular plant botanists (cf. Takhtajan, 1986). The alternations are minor and mostly those, which allow to use the information from check-lists made to country level: (1) Arabian Peninsula and Iran are included totally in the Palearctic although their southern parts traditionally belong to Paleotropics. Since this region is very xeric and poor in mosses, its inclusion in the consideration does not affect much the results; the only exception has been made for Socotra Island, where many tropical species of mosses occur, so this island is not included. (2) North Africa is restricted to the 5 Mediterranean countries (Morocco, Algeria, Lybia, Tunisia and Egypt); West Sahara can be included, but no one moss is known from there so far.

As was shown by Ignatov (1993), the moss species diversity in non-tropical Eurasia is higher in oceanic regions, whereas waste inland territories have poorer moss floras. Somewhat expanded version of this scheme is represented in Fig. 1. It allows to delimit rich East Asian moss flora; analysis of the latter is a special task, which is outide of the scope of the present paper. The rest part of Palearctic is called here the Western and Northern Palearctic, i. e. Palearctic excluding ter-

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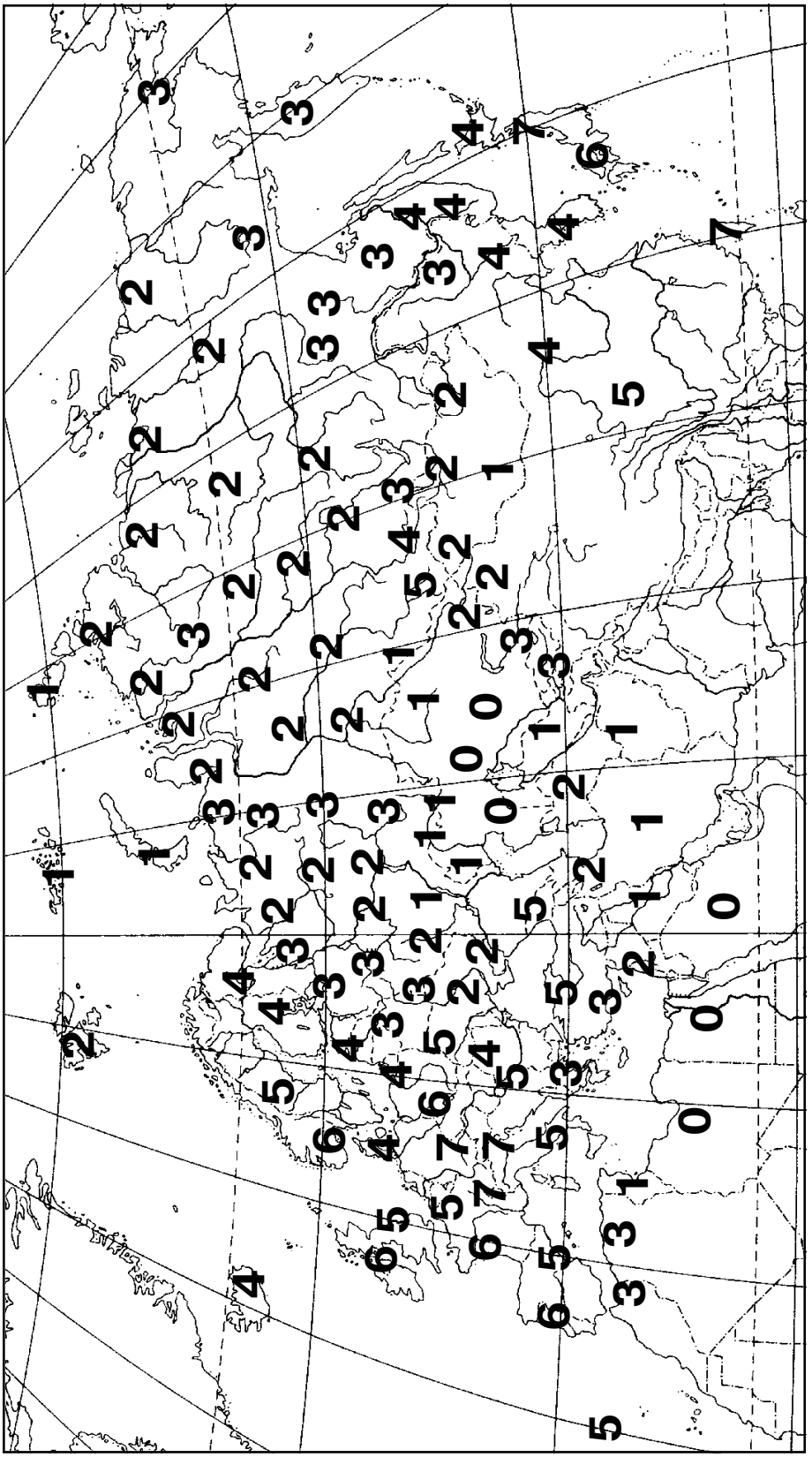


Fig. 1. The number of species in regional moss floras approximated for area of 100,000 sq. km. (0 - <100 species, 1 - 100-199 species; 2 - 200-299, etc.).

ritories of China, Korea, Japan, and Russian Far East. Mongolia is included because its moss flora is very similar to that of South Siberia. India and Pakistan are not included, while Afganistan is included.

Thus delimited, the Western and Northern Palearctic (cf. Fig. 3), is corresponding approximately to EUR + AS1 + AS5 + AFR1 by Index Muscorum, with some minor changes explained above. This territory is ca. 40 Mkm², or 27% of the World Terra.

Two comments are necessary: on the map in Fig. 1, and on the exclusion of the Russian Far East from this analysis.

Comment 1: Fig. 1 shows the number of species in Western and Northern Palearctic for the area of 100 Kkm². This size of area was chosen primarily for practical reasons, since many political and administrative units have more or less similar sizes, and therefore many bryogeographical publications and checklists refer to an area of such size. Making approximation to 100 Kkm², I kept in mind both published floras and lists, distributional maps of some species, my own field experience and estimation of the level of exploration. So, the map is not totally free from my own subjectivism. However the present unevenness in the level of exploration does not allow to use more formal (and more objective) methods. Such methods were much developed for analysis of species diversity of vascular plants (cf. Malyshev, 1975), but they hardly can be applied to very uneven data.

Some examples of estimation can be as follow: (1) during the trip to Upper Bureya River in Khabarovsk Territory, Iwatsuki, Tan & Ignatov collected in one month during 200 km trip ca. 270 species, and ca. 15 more species were found in that area by other collectors (Ignatov & al., 2000). No other big collections were made in neighboring ca. 500 km. The diversity of 100 Kkm² must be no less than 300. Also we showed, that the northern limits of many East Asian species lie in more southern areas, so the diversity in 100 Kkm² hardly will reach 400 species. So, this place is evaluated as 3 (300-399 species).

(2) Only maximal species diversity is shown in the map: for example in Poland (677 species/313 Kkm²) the richest are mountain regions in the South, where diversity at places must be over 600 species for 100 Kkm². So in the map is put 6 (600-699 species), despite in the lowlands of central and northern Poland the square of 100 Kkm² can be chosen with species diversity probably 4 (400-499 species).

(3) Another example is Sweden (753 species/449 Kkm²). Though the diversity is high, there are many species of southern and oceanic distribution, which are restricted only to South and South-East of Sweden, while some northern species occur only in mountains in the North of the country. Therefore diversity in Central Sweden is evaluated as 5 (500-599 species).

The changes in the map in Fig. 1 seem to be possible for some areas evaluated as "2", which might be shifted to "3" (i. e. from 200-299 to 300-399), in some parts of the Eastern Siberia where rock outcrops are widespread. However the numbers in Eastern Europe and Western Siberia will probably be never changed, because these areas have low diversity of habitats (lack of any rocky substrates), so local floras rarely reach even 200 species (for example in some forest reserves, at 1–10 Kkm²).

Though this evaluation is rather rough, it allows to summarize the main patterns of moss diversity within the Western and Northern Palearctic as follow. The number of species in 100 Kkm² in most of boreal inland regions of the Western and Northern Palearctic is between 200 and 400 species, dropping to below 100 species in most xeric areas of Central Asia, but raising to 400-700 species (rarely exceeding 700) in oceanic climates. The number of species increases again in the mountains of South Siberia (to more than 500 species). The explanation of this pattern is rather obvious. Mosses in general are dessication-densitive organisms, so their diversity is raising in the areas where constantly humid habitats are more numerous and diverse. This is the difference from the vascular plants which are more dependent upon the warm-cool gradient than the humid-xeric one, so diversity of vascular plants is decreasing mainly from South to North (Malyshev, 1975; Ignatov, 1993).

Comment 2: The moss flora of the southern part of Russian Far East (as defined by Ignatov & Afonina, 1992, Ignatov, 1993, i. e. northwards to Amur River basin inclusively, and includin Sakhalin and Luril Is.) is very peculiar, and it must be discussed together with those of China and Japan. The reasons for the not inclusion of this part of Russian Far East in analysis are as follow: (1) There are 110 moss species in southern Russian far East, which do not occur in other parts of Western and Northern Eurasia. Most of them are in common with China and/or Japan. Among them are many peculiar East Asian endemic genera (*Actinothuidium, Boulaya, Dolichomitriopsis, Dozya, Fauriella, Hondaella, Hylocomiopsis, Mamillariella, Miyabea, Okamuraea, Pseudoleskeopsis, Rigodiadelphus*), as well as representatives of many genera with a principally temperate distribution (*Brachy-*

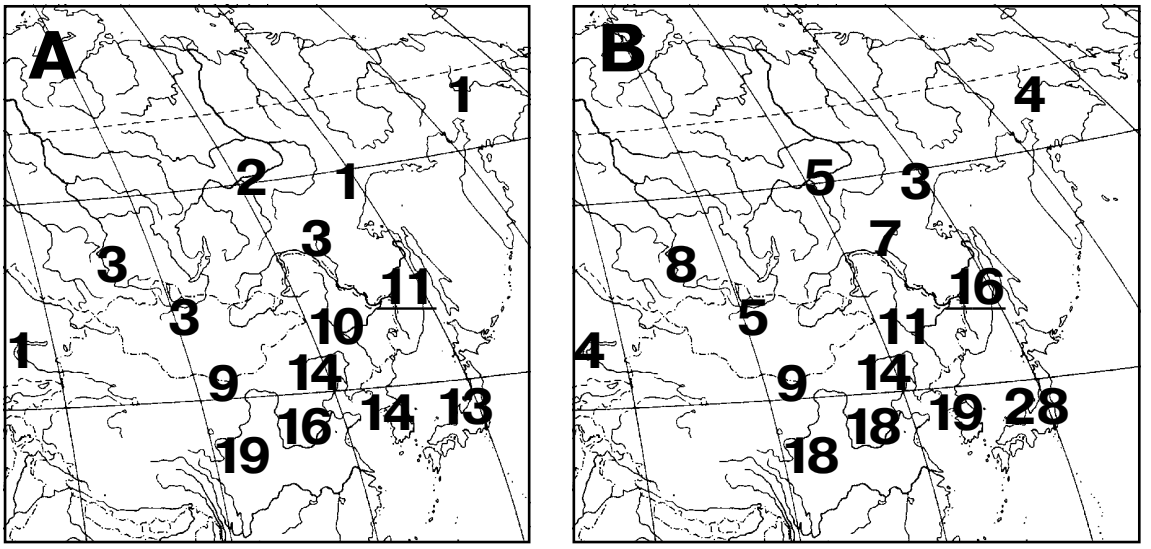


Fig. 2. The number of species of the genus *Entodon* (A) and of the family Thuidiaceae (B) in the Russian Far East (underlined) and neigboring areas, showing that the latter is more similar with NE China and Japan, than with Siberia.

menium, Cryphaea, Glyphomitrium, Homaliadelphus,Hypopterygium,Macromitrium,Pylaisiadelpha, Rauiella, Schwetsckeopsis, etc.). The diversity of some more temperate families and genera is suddenly raising on transition from Siberia to the southern Russian Far East (Fig. 2). Also, the southern part of the Russian Far East appears to be an area with a rich diversity of mosses situated at the edge of the relatively poor and monotonous territory of North Asia (Fig. 1).

METHODS

The study of moss diversity of the Western and Northern Palearctic as they are defined above was based on a database compiled from from various publications in spring of 1999. The main sources of information are listed below:

– Europe: Düll (1984, 1985, 1992) with subsequent additions and corrections from Corley & Crundwell (1991) and from recent checklists and atlases for countries which have them: Bjornoya & Denmark & Faroes & Finland & Iceland & Jan Mayen & Norway & Spitzbergen & Sweden (Söderström,1996, 1998); British Isles (Hill & Preston, 1998); Czech Republic (Vana,1997); Germany (Düll & Meinunger, 1989, 1994ab); Greece & Crete (Düll, 1995); Italy & Sardinia & Sicily (Cortini Pedrotti, 1992); Luxemburg (Werner,1993); Netherlands (Touw & Rubers, 1989); Poland (Ochyra & al., 1992); Spain (Casas, C. 1991).

– Territory of the former USSR: Ignatov & Afonina (1992).

– Macaronesia: Eggers (1982); Hedenäs (1992); Dirske & al. (1993).

– Middle East: Frey & Kürschner (1991), with updating for Israel from Hermstadt & al. (1991).

– Mongolia: Abramov & Abramova (1983).

– North Africa: Ros (unpubl.)[1].

This data were supplemented from the recent literature.

Information is referred mostly at the country level, except for the territory of the former Soviet Union where the data referred to are grouped under the subdivisions of the former USSR (Ignatov & Afonina, 1992). Some of the former USSR republics, now separate countries, are being combined together. Jugoslaviya was treated within the old borders dated back to the 1980s. For the former USSR and Mongolia which have extensive territories, a subdivision to 21 and 4 subregions was used respectively. The isolated islands were considered as separate bryogeographical units: Corsica,Sicily,Sardinia,Balearic Is.,Faroe Is.,Bjornoya (Bear Island),Jan Mayen,Svalbard (Spitzbergen), Acores, Canary Is., Madeira. So altogether this database covers 83 territorial units within the Western and Northern Palearctic.

Outside this area, my database included information obtained from other parts of the world: North America (Anderson & al., 1990), tropical

[1] – Later these data were published by Ros & al. (1999), however the database used data from file of Dr. R. M. Ros, kindly presented to my disposal before publication.

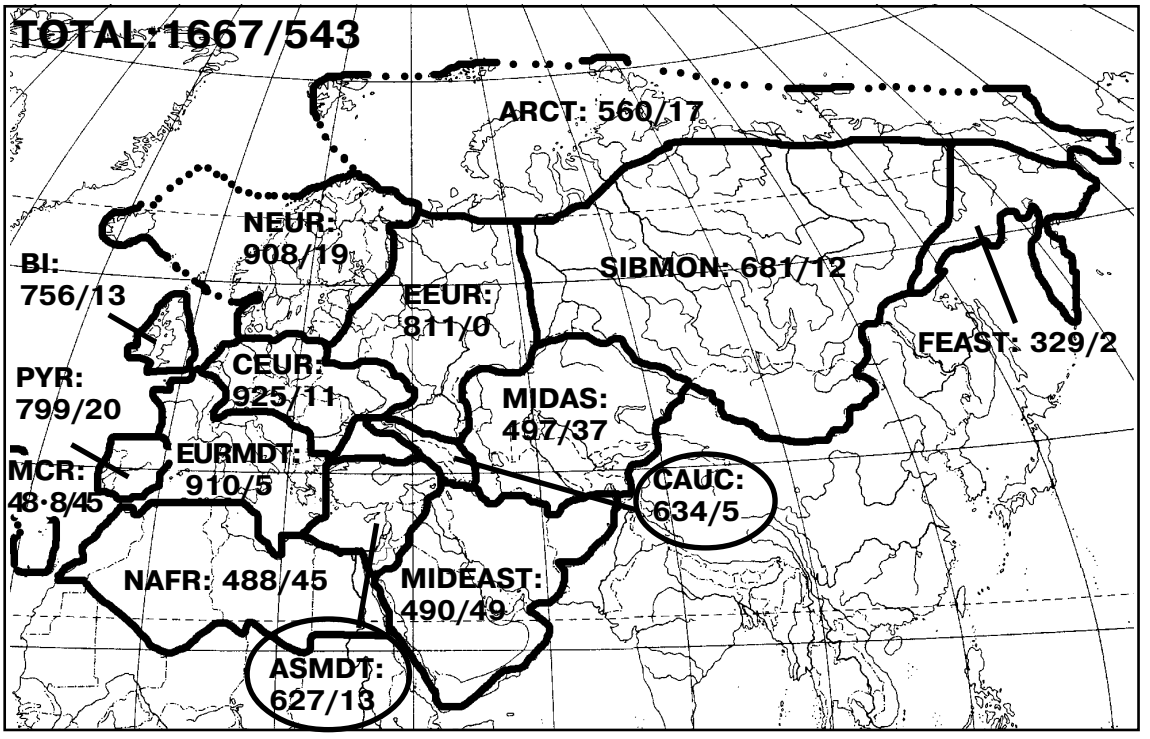


Fig. 3. The main regions of the Western and Northern Palearctic with the number of species for each region/endemic species of this region.

Africa (O'Shea, unpubl.), China (Redfearn & al., 1996), Japan (Iwatsuki, 1991). Since there is no modern checklist of India and Himalayas, the data of distribution are based mostly on the indication of As3 in Index Muscorum, with post-consultation of various sources of information when necessary.

The diversity data of 83 units of the Western and Northern Palearctic was further grouped into 15 larger regions (Fig. 3) in order to use in analysis regions more equal in size and level of exploration. This grouping is as follow (the number in brackets after the abbreviation means the number of entities in database; square brackets have the explanation of the regions of the former USSR):

ARCT (5) – Arctic, including Russian Arctic, i. e. exUSSR: ARC (EURO, WS, ES, BE) + Svalbard;

ASMDT (7) – Asian Mediterranean, including Turkey, Cyprus, Syria, Lebanon, Israel, Jordan, Sinai Peninsula of Egypt;

BI (2) – British Isles, including United Kingdom and Ireland;

CAUC (1) – Caucasus, including exUSSR: CAUC [Armenia, Georgia, Azerbaijan, Russian Cis-Caucasia];

CEUR (14) – Central Europe, including Belgium, Luxemburg, Netherlands, Germany, Poland, Czechia,Slovakia,Switzerland,Austria,Hungary,Romania,Bulgaria,exUSSR: EUR (W,K) [Moldova and Ukraine];

EEUR (6) – East Europe, including exUSSR: EUR (BLR, NE, C, E, N-UR, S-UR) [Belorussia, Central European Russia, and Ural Mts.];

EURMDT (9) – European Mediterranean, including France, Corsica, Italy, Sardinia, Sicily, exJugoslaviya s. l., Albania, Greece, Crete;

FEAST (1) – Far East, including exUSSR: FAR EAST (N);

MCR (3) – Macaronesia, including Azores, Canary Is., and Madeira;

MIDAS (1) – exUSSR: MID AS [Kazakhstan, Uzbekstan, Tadjikstan,Kirgyzstan,Turkmenstan];

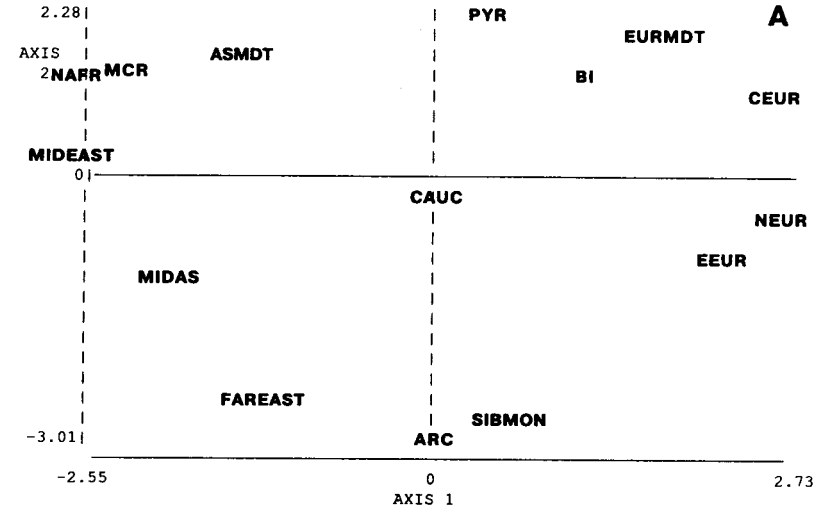
MIDEAST (8) – Middle East, including Saudi Arabia, Yemen (without Socotra), Oman, U.A.E., Bahrain, Qatar, Kuwait, Iraq, Iran, Afganistan;

NAFR (5) – North Africa, including Morocco, Algeria, Tunisia, Lybia, and Egypt (without Sinai);

NEUR (11) – North Europe, including Iceland, Faroes, Bjornoya, Jan Mayen, Norway, Sweden, Denmark, Finland, exUSSR: EUR (NW, B) [Russia: Kola Peninsula, Karelia, Leningrad/St.-Peterburg Province, Kaliningrad Province; and Baltic countries: Estonia, Latvia, Lithuania];

PYR (3) – Pyrenean Peninsula, including Portugal, Spain, and Baleares;

SIBMON (7) – Siberia and Mongolia, including exUSSR: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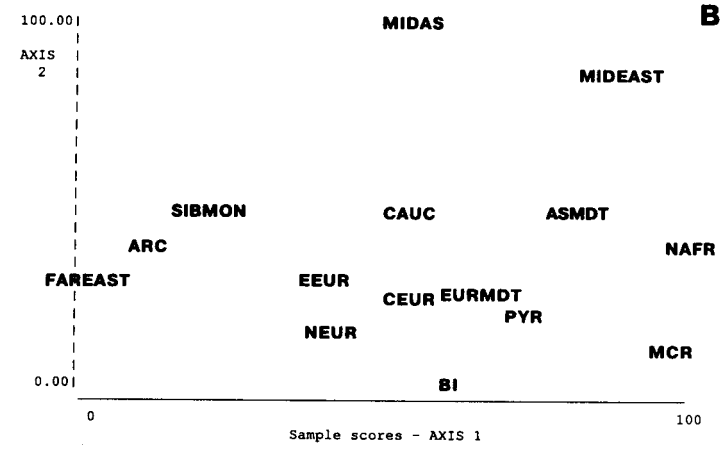
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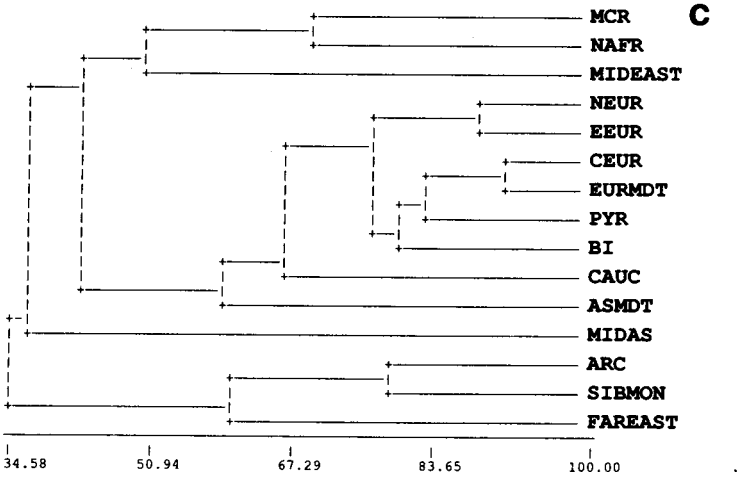
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SIB (W, E, S) + Mongolian Republic (subdivided into 4 regions: Mongolian Altai, Khangai, Khentei, and the rest of territory).

A big job tackled in doing this comparison has been to correlate spacies names in publications by different authors. When in doubts, the worldwide monographs (for example, Zander, 1993; Lewinsky, 1993, Koponen, 1981, etc.) were used as the standard and final definition of level of taxa. However in many groups which lack a modern revision, the selection of the better taxonomic status among the existing opinions was done myself. Many varieties of mosses which are in use only in a few countries but not recognized as distinct taxa in other countries were ignored. The so-called "hanging" varieties (those fail to be synonymized yet while their species already were reduced to synonymy) were also ignored. This approach made the species number in some countries different from those given in the original publications.

RESULTS AND DISCUSSION

A. General diversity of mosses of the Western and Northern Palearctic

Based on the above approaches, moss flora of the Western and Northern Palearctic includes 1759 taxa: 1667 species, 3 subspecies and 89 varieties. This number includes some little known and dubious species, which probably will not survive the further revisions, however a number of species probably will be described in the future. My subjective expectation is that the final number of moss species in the Western and Northern Palearctic will be between 1500-1600 (using the present species concept, i. e. not including possible addition of sibling species).

This species diversity (1667 species/40 Mkm^2) is comparable with the number for USA+Canada (Anderson & al., 1990): 1320 species/19 Mkm^2.

Especially rich in species in Western and Northern Palearctic are regions of the Northern Europe, Central Europe and European Mediterranean (without Iberian Peninsula), each having more than 900 species (Fig. 3). The regions of the British Isles and Iberian Peninsula have 756 and 799 species respectively, but considering their smaller territories one can consider them within the group of the richest moss floras of the Western Europe.

The species composition of 15 main regions was analyzed using the Multivariate Statistical Package 2.2a. Since this software allows only 750 lines in data matrix, species of limited (in 1-4 regions) and also of very wide (11-15 regions) distribution were omitted. The ordination of regions made by principal component analysis (Fig. 4A) and correspondence analysis (Fig. 4B) has a good correspondence with their geographical positions. This coincidence can be interpreted as that the present knowledge of mosses within the Western and Northern Palearctic is relatively complete. The dendrogram of cluster analysis (Fig. 4C) shows relatively isolated position of regions of Arctic+ Siberia+Northern Far East, and this group stands somewhat separately in the result of the correspondence analysis (Fig. 4B). The most probable this isolation can be explained by the negative specificity of these regions, i. e. not by presence of its own species, but by the absence of many species distributed in most of the other territories but not here. Another conclusion from the cluster (Fig. 4C) and correspondence (Fig. 4B) analysis is the rather high similarity of all the European regions. The third less solid group (Fig. 4C) is the areas along the southern border of the area: Middle Asia, Middle East, Asian Mediterranean, European Mediterranean, North Africa and Macaronesia; they have many specific species, which however are usually more specific for only one of this area, with quite a few species common for several of them, but not penetrating to the Central and Northern Europe (see Tabl. 3 below).

The interesting is the picture of the occurrence frequencies of species (Fig. 5). Usually such distribution is approximated by the hyperbolic function (Y=k/X), where k - constant. However here this approximation is not clear. (1) First, the number of species in only one region looks too high. Obviously, this is affected by the number of superfluously described species, and also by recently described species not yet recognized elsewhere. After further studies on taxonomy and better flora exploration this number will probably be reduced to between 200 and 300. (2) Numbers of species known in 2-5 regions are not higher than those in 6-12 regions. This fact can be explained that most of European regions of the current division are closely connected each other and phytogeographically are better understood as a single natural unit (cf. with the rather solid group drawn by statistical analysis for most of western regions). The clusters of 3 continental regions (Arctic + Siberia + Northern Far East), as well as the cluster of xeric southern regions are

← Fig. 4. The results of analysis of moss floras of regions of the Western and Northern Palearctic by principal component (A), correspondence (B) and cluster analysis (C). Note the arrangement of regions is well corresponding with that on the geographic map.

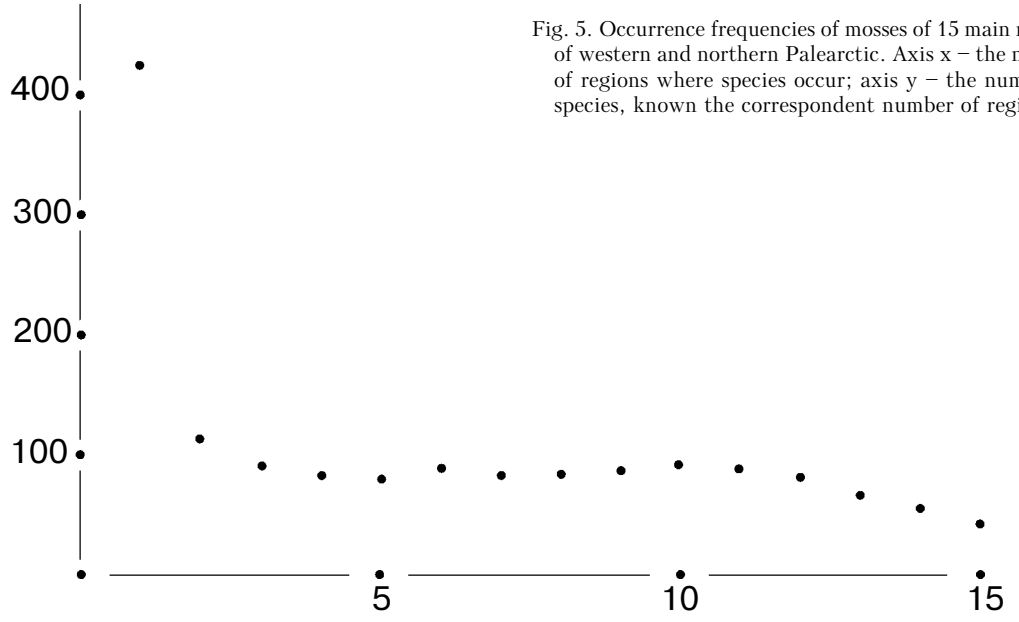

Fig. 5. Occurrence frequencies of mosses of 15 main regions of western and northern Palearctic. Axis x – the number of regions where species occur; axis y – the number of species, known the correspondent number of regions.

segregated mostly by absence, not by presence of specific species, so they are not able to raise the number of species occurring in 2-3(-5) regions.

B. Main geographic elements contributing the diversity of mosses of the Western and Northern Palearctic

The number of species occurred in all 15 regions is 44, or 2.6% only. The analysis of the former USSR (21 regions) revealed a very close value, ca. 3.2% (1157 species, 37 in all 21 regions), and my calculation for the West European countries is also very similar. I used for this only recently checklisted countries (British Isles, Crete, Czechia, Faroes, Finland, Germany, Greece, Netherlands, Spain, Iceland, Italy, Luxemburg, Norway, Poland, Sardinia, Sicily, and Sweden). Their total moss flora includes 1210 species with 39 (3.2%) species occurring in all of them. So, probably this percent will be not changed much after the better exploration in the future.

The species occurring in all regions of the Western and Northern Palearctic are as follow: *Amblystegium serpens* (Hedw.) B. S. G., *A. varium* (Hedw.) Lindb., *Aulacomnium palustre* (Hedw.) Schwaegr., *Brachythecium albicans* (Hedw.) B. S. G., *B. rivulare* B. S. G., *B. salebrosum* (Web. et Mohr) B. S. G., *Bryoerythrophyllum recurvirostrum* (Hedw.) Chen, *Bryum argenteum* Hedw., *B. caespiticium* Hedw., *B. pallescens* Schleich. ex Schwaegr., *B. pseudotriquetrum* (Hedw.) Gaertn. et al., *Calliergonella cuspidata* (Hedw.) Loeske, *Ceratodon purpureus* (Hedw.) Brid., *Cratoneuron filicinum* (Hedw.) Spruce, *Ctenidium molluscum* (Hedw.) Mitt., *Dicranoweisia crispula* (Hedw.) Lindb., *Dicranum scoparium* Hedw., *Ditrichum flexicaule* (Schwaegr.) Hampe, *Encalypta vulgaris* Hedw., *Fissidens bryoides* Hedw., *Fontinalis antipyretica* Hedw., *Funaria hygrometrica* Hedw., *Grimmia ovalis* (Hedw.) Lindb., *Hypnum cupressiforme* Hedw., *Leptobryum pyriforme* (Hedw.) Wils., *Leptodictyum riparium* (Hedw.) Warnst., *Palustriella commutata* (Hedw.) Ochyra, *Philonotis caespitosa* Jur., *P. fontana* (Hedw.) Brid., *Pleurozium schreberi* (Brid.) Mitt., *Pogonatum urnigerum* (Hedw.) P. Beauv., *Pohlia cruda* (Hedw.) Lindb., *P. nutans* (Hedw.) Lindb., *P. wahlenbergii* (Web. et Mohr) Andrews, *Polytrichum commune* Hedw., *P. juniperinum* Hedw., *Pylaisia polyantha* (Hedw.) Schimp., *Rhytidiadelphus triquetrus* (Hedw.) Warnst., *Schistidium apocarpum* (Hedw.) B. S. G., *Sphagnum capillifolium* (Ehrh.) Hedw., *Syntrichia ruralis* (Hedw.) Web. et Mohr, *Tortella fragilis* (Hook. et Wilson) Limpr., *T. tortuosa* (Hedw.) Limpr., *Trichostomum tenuirostre* (Hook. et Tayl.) Lindb.

However despite of this low number of species in all regions, there are 551 species which occur in 9-15 regions. Another way to figure out this value is to

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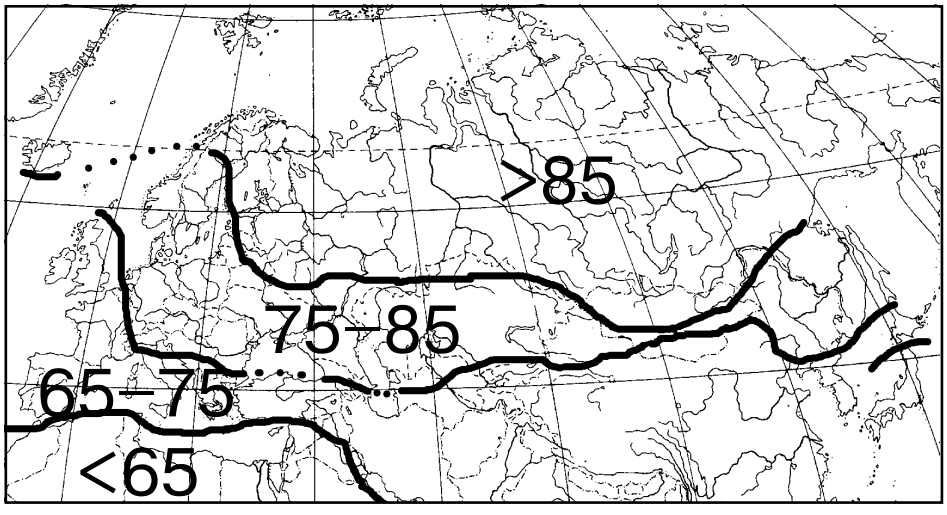

Fig. 6. The percent of species in common with North America in 83 regional floras of the Western and Northern Palearctic.

find a number of common species between some remote regions – for example, for Siberia and Germany in common are 471 species (or 69% of flora of Siberia). In the other words, about one third of moss species of the Western and Northern Palearctic are relatively widespread throughout its territory.

Another big geographic group of species are those concentrated (within the territory of the Western and Northern Palearctic) in Southern and Western part of Europe (cf. Fig. 1). This group includes (400-)500-600 species, depending of how far to the North and East one expand the concept of this centre of diversity. This group is often divided into more western (Atlantic) and more southern (Mediterranean) elements. This approach brings interesting results in more local analysis which allows to take into consideration distribution within particular countries, in different vegetational zones and altitudinal belts and also costal and inland parts of countries. However the present country-level analysis is probably too rough for such segregation: too few species can be referred definitely to Atlantic or Mediterranean elements, while much more species have a combined Atlantic+ Mediterranean distribution (cf. Fig. 9).

The increasing of specificity towards Atlantic + Mediterranean area can also be illustrated by the comparison of moss floras (counted for species only, i. e. not including varieties) of 83 regions of the Western and Northern Palearctic with that of the North America (Fig. 6). This picture shows that the more to the south, the less is the percent of circum-Holarctic species. The comparison of moss floras of two well-studied areas of South and North Europe, for example Sweden and Spain, provide another good picture of the distribution of circum-Holarctic species. Nearly the same number of species occur in Sweden but not in Spain and in Spain but not in Sweden, however among the former 3/4 are the species common with the North America, whereas in the latter this value is only 1/3.

The number of principally East Asian species penetrated to the territory of the Western and Northern Palearctic (mostly to South Siberia) is 70-80 species only. Species confined to the xeric territories of the Middle Asia, Middle East and North Africa are more than 200, but most of them are little-known and narrow-ranged "endemics". Further studies are needed to understand the real number of species in this group. Other species can be classified into a number of less well-delimited geographical elements.

Speaking roughly, about a third of species in the Western and Northern Palearctic are widespread, the second third – species confined in this area to Mediterranean+Atlantic region; and the third third – miscelaneous smaller groups and poorely known taxa.

C. The taxonomic spectra of mosses of the Western and Northern Palearctic

The count of number of species by families in moss flora of the Western and Northern Palearctic is illustrated in Table 1. The family number one is Pottiaceae, which is much richer than the other families, even comparing with Bryaceae, which has a reputation of much inflated in number of species. The third and fourth families, Grimmiaceae and Dicranaceae, have only about one third of species number of Pottiaceae. The percent of endemic species in Pottiaceae (46%) is higher, that the average for the Western and Northern Palearctic (32.5%); however many other large families also have percent higher than average (Bryaceae, Grimmiaceae, Brachytheciaceae, Orthotrichaceae, Fissidentaceae, etc.). Therefore, one can conclude,

Tabl. 1. The number of genera and species in the largest moss families (left) and families most rich in endemic species (right) in the flora of the western and northern Palearctic

ALL SPECIES			ENDEMIC SPECIES	
genera/species	family	N°	family	genera/species (percent to all species)
40/311	Pottiaceae	1	Pottiaceae	26/147 (46%)
12/216	Bryaceae	2	Bryaceae	6/96 (44%)
8/118	Grimmiaceae	3	Grimmiaceae	3/47 (40%)
23/107	Dicranaceae	4	Brachytheciaceae	11/40 (41%)
18/98	Brachytheciaceae	5	Funariaceae	7/29 (64%)
22/77	Amblystegiaceae	6	Fissidentaceae	1/27 (55%)
7/70	Orthotrichaceae	7	Orthotrichaceae	5/26 (37%)
1/59	Sphagnaceae	8	Dicranaceae	7/13 (12%)
18/52	Hypnaceae	9	Hypnaceae	6/13 (25%)
1/49	Fissidentaceae	10	Ditrichaceae	4/9 (32%)
9/45	Funariaceae	11	Leskeaceae	4/9 (32%)
7/39	Mniaceae	12	Cinclidotaceae	1/7 (88%)
9/36	Polytrichaceae	13	Amblystegiaceae	5/6 (8%)
8/30	Bartramiaceae	14	Plagiotheciaceae	4/5 (17%)
6/29	Plagiotheciaceae	15	Seligeriaceae	4/5 (20%)
9/28	Leskeaceae	16	Neckeraceae	2/5 (38%)
8/28	Ditrichaceae	17	Ephemeraceae	1/5 (68%)
5/24	Seligeriaceae	18	Sphagnaceae	1/6 (10%)
5/24	Splachnaceae	19	Thamnobryaceae	1/5 (71%)
2/18	Encalyptaceae	20	Polytrichaceae	3/4 (11%)
6/17	Thuidiaceae	21	Thuidiaceae	2/4 (24%)
1/14	Andreaeaceae	22	Echinodiaceae	1/4 (100%)
300/1667	67 families		42 families	128/543 (32.5%)

that the number of species in Pottiaceae in the region is not more inflated comparatively with the other large families, and its first position is real, not much affected by less sufficient knowledge. Exceptionally low is the percent of endemics in four families: Amblystegiaceae (8%), Sphagnaceae (10%), Polytrichaceae (11%), and Dicranaceae (12%). These families are especially rich in Circum-boreal and Circum-polar species, occurring also in North America. Another reason of their low endemism might be also their better taxonomy – being important constituents of mire and tundra vegetation these families were more carefully investigated.

The ratio of number of species Pottiaceae to Dicranaceae in local floras was introduced by Popova (1998) as an useful character for moss flora comparison in Central Russia. In the territory of the Western and Northern Palearctic it also exhibits a quite logical pattern, ranging from a below 1 in the North, 1-2 in most part of Europe, 2-4 in moderately xeric Mediterranean climates and ca. 10 and more in many xeric areas of North Africa, Middle East and Middle Asia (Fig. 7). Note, however, that increase of this ratio from North to South is not a general rule. In more humid areas of East Asia, like Japan (P:D = 1.12) and China (P:D = 1.15) this ratio is closer to Eurasian Arctic (P:D = 0.88), than to the whole territory of Europe (P:D = 2.05). By this rate Europe has more xeric moss flora than the North America, i. e. U.S.A. + Canada (P:D = 1.55), and this is obviously explained by the presence of big xeric neighboring territories of the Middle East, including Asian Mediterranean countries (P:D = 5.36) and the North Africa (P:D = 9.66).

The genera arranged in number of species are listed in Table 2. Note that the largest of them have higher percent of endemic species, comparatively with their families (*Bryum*–53/Bryaceae–44; *Totrula* [sensu Zander, 1993]–60/Pottiaceae–46; *Schistidium* [including species described by Blom, 1996, 1998]–66/Grimmiaceae–40). These proportions are certainly a result of the lack of modern large-scale revisions of these genera. *Schistidium* was revised recently by Blom (l. c.), but only for part of Europe. Next are *Orthotrichum* and *Grimmia*, both recently revised in Europe (Lewinsky-Haapasaari, 1995; Greven, 1995), with rich data on the occurrence in the other parts of the world. Note, that percent of endemic species in two latter genera is 34-39% [see also footnote on previous page], less than that for the first four genera in

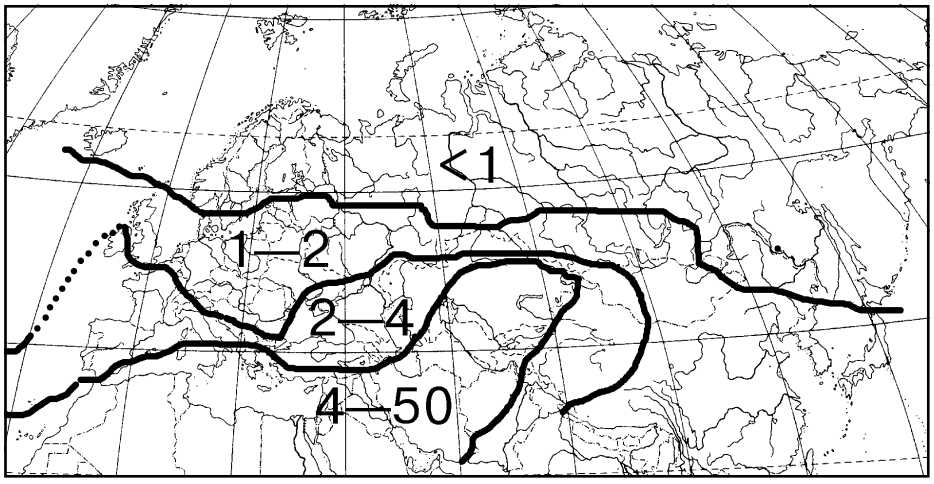

Fig. 7. The ratio of number of species of Pottiaceae to Dicranaceae in local floras of the Western and Northern Palearctic.

Tabl. 2. The number of species in the largest moss genera in the moss flora of the Western and Northern Palearctic (boldfaced are genera with the higher percent of endemics)

Genus	endemic species	all species	percent of endemics
Bryum	80	151	53.0
Tortula	34	57	59.6
Fissidens	27	49	55.1
Schistidium	27	41	65.9
Orthotrichum	18	46	39.1
Grimmia[1]	17	49	34.7
Weissia	17	28	60.7
Didymodon	14	32	43.8
Barbula	12	22	54.5
Entosthodon	**11**	**14**	**78.6**
Brachythecium	10	38	26.3
Funaria	10	17	58.8
Pohlia	10	38	26.3
Rhynchostegiella	**9**	**11**	**81.8**
Cinclidotus	7	8	87.5
Hypnum	7	26	26.9
Microbryum	7	11	63.6
Syntrichia	6	22	27.2
Tortella	6	16	37.5
Bryoerythrophyllum	5	10	50.0
Ditrichum	5	14	35.7
Ephemerum	**5**	**7**	**71.4**
Eurhynchium	5	13	38.5
Pseudoleskea	5	13	38.5
Pterygoneurum	5	9	55.6
Sphagnum	5	59	8.8
Thamnobryum	**5**	**7**	**71.4**
Trichostomum	5	9	55.6

[1] – The revision of Munoz & Pando (2000), which became available to me after this paper was already prepared, reduce these numbers to 7/40/17.5% correspondingly.

the Table 2 (53-66%).

Especially rich in endemics in the Western and Northern Palearctic are *Entosthodon*, *Ephemerum*, *Thamnobryum*, *Rhynchostegiella* and *Cinclidotus,* which delimit the Western Palearctic centre of speciation in these genera. Two latter genera are discussed below.

D. Species endemism in mosses of the Western and Northern Palearctic

As was found above (Fig. 3), the percent of endemic species in each individual region is ranging from 0% in the East Europe to 10% in the Middle East. In more northern and better known floras of Western Europe this percent is ca. 1-2%. But even this small number is probably an overestimation, because many of these endemics belong to critical genera: 6 of 19 endemics of Northern Europe are *Schistidium* species (the species concept of Blom (1996, 1998) was used in the present analysis), 12 of 17 endemics of Arctic belong to *Bryum*, etc. The high percent of endemics in xeric areas of North Africa, Middle East and the Middle Asia is also probably inflated (for example, 22 of 37 endemics of Middle Asia are species of *Bryum*). Probably only in Macaronesia the high percent of local endemics, 9.2%, more or less approaching to the true number.

However in the whole area of the Western and Northern Palearctic there are 543 species and 71 varieties which are absent in the database for North America, China, Japan, Tropical Africa, and other regions (though for other regions data might be somewhat incomplete).

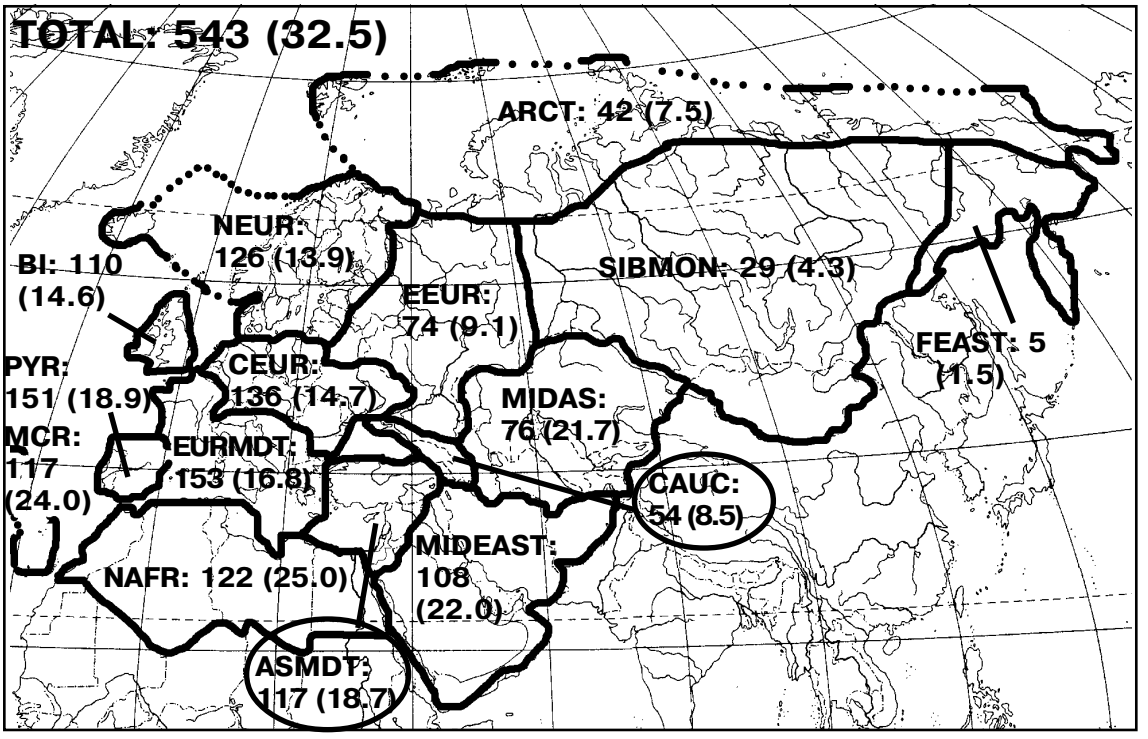

Fig. 8. The main regions of the western and northern Palearctic with the number/percent of endemic species of the whole area of the western and northern Palearctic in each individual region.

Therefore, the endemism for the whole area of the Western and Northern Palearctic is as high as 32.5%.

Comparing with about 1-(2)% for some individual regions of the Western Europe and even with 9.2% for Macaronesia, this 32.5% looks too high and one can suspect that this percent is too inflated by little known "endemics" from less revised areas. However, the percent of endemics of the whole area (i. e. of 543) in floras of individual areas in Western Europe is rather high, ranging from 13 to 19% (Fig. 8), in contrast to 1-2% of endemics for each of these areas.

This means that the regional division of Europe used here deal with the areas which are smaller than the mean areal of European endemic species. This fact can be illustrated by the Tabl. 3, showing that one-region endemism is a characteristic of relatively less revised floras of Middle East, Middle Asia and North Africa, whereas most of endemics of Europe occur in several regions (cf. also Fig. 9). I believe that this difference depends mainly on the level of exploration, than on the real situation. Note however that the territories of these xeric regions are larger than in Europe [Middle East (8,83 Mkm^2), Middle Asia (3,98 Mkm^2), North Africa (5,65 Mkm^2) // North Europe (1,38 Mkm^2), Central Europe (1,48 Mkm^2), European Mediterranean (1,27 Mkm^2)]. Also, the species diversity in the xeric regions has island-pattern, being confined to not many isolated oasises. This imply the possible higher percent of real local endemics in this region, but at moment this can be just a hypothesis, which must be carefully tested by taxonomic studies.

So, though it is clear that the number of endemics is somewhat inflated by species of poorly known groups, the real endemism of the Western and Northern Palearctic can be estimated as 20±5%. The similar value, 23%, has been found for the North America (Schofield, 1980).

E. Generic and familial endemism in mosses of the Western and Northern Palearctic

The endemism at generic level is rather low and includes 10 to 16 genera, depending on acceptance of generic status for some of them. All generic endemics include only one species.

Only 5 endemic genera and 3 putative endemis (or subendemic?) have more or less wide distribution (Figs. 9a-h). Among endemics only (1) *Cheilothela* is a well-reputated genus, recently revised by Buck (1981); (2) *Funariella* was

Tabl. 3. The widespreadness of endemics species of the western and northern Palearctic and some of its regions.

Number of regions where endemic species occur	Number of endemic species Region					
	Middle Asia	Middle East	whole area	Central Europe	British Isles	Eastern Europe
1	37	50	283	11	13	0
2	8	7	73	11	6	10
3	2	5	36	11	11	7
4	2	4	31	15	16	5
5	1	3	17	13	9	6
6	4	8	23	17	13	7
7	6	9	16	13	8	7
8	5	6	18	18	11	11
9	4	9	14	14	11	6
10	4	4	9	9	6	9
11	1	1	2	2	2	2
12	2	2	2	2	2	2
13	2	2	2	2	2	2
total	76	108	543	136	110	74

recently segregated from *Entosthodon* by Sérgio (1988); (3) *Pottiopsis* – from *Trichostomum* (Blockeel & Smith, 1998); (4) *Ptychodium* is considered by some authors within *Lescuraea* (cf. Lawton, 1957; Smith, 1978); (5) *Trochobryum* is not always segregated from *Seligeria* (cf. Smith, 1978; Vitt, 1976).

Putative endemics (or subendemic) are as follow. (1) *Leptobarbula* (Fig. 9c) is a good genus, cited by Zander (1993) also for As 3, but I found no records in local literature for that area. (2) *Habrodon* is widespread in Europe (Fig. 9g) with the only record from Japan, by sterile specimens (Saito, 1974); the drowning in Saito paper seems admit other interpretations, so additional confirmation is needed. *Habrodon* is placed usually in Leskeaceae, but its smooth exostome teeth are quite different from other Leskeaceae genera, and probably it is closer to genera of Leucodontaceae-Crypheaceae complex, and maybe it needs its own subfamily. (3) *Hyocomium* similarly was reported only once in Sichuan Province of China (Chen, 1978) after a very long disjunction from Europe and Turkey (Fig. 9h); this record also needs additional confirmation. *Hyocomium* was segregated in a separate family by Hedenäs (1992), but I prefer to agree with Nishimura & al. (1984), who placed *Hyocomium* into Ctenidiaceae.

Other 8 genera have narrow distribution. Among them, Macaronesian *Alophozia* and *Andoa* are relatively common within their areas in Macaronesia. Other local generic endemics are known up to now only from their type locality or nearby: *Bardunovia*, Baikal area in South Siberia (Ignatov & Ochyra, 1995)[1], *Nobregaea* – Madeira (Hedenäs, 1992); *Ochyraea* – Slovakia (Vana, 1986); *Pictus* – Britain (Townsend, 1982); *Scleropodiopsis* – Altai Mts. of South Siberia (Ignatov, 1998); *Steppomitra* Vondracek et Hadac – Iraq (Vondracek, 1965). The last genus is probably not distinct from *Entosthodon* (cf. Fife, 1985).

Orthodontopsis, described from mountains of South Siberia (Ignatov & Tan, 1992) was not reported from other regions yet, but according to Tan (pers. com.), *Orthodontium bilimbatum* X. J. Li et D. C. Zhang recently described from Yunnan (Zhang & Li, 1996) is identical with *Orthodontopsis bardunovii* Ignatov & Tan. Description and illustration of *O. bilimbatum* are also agree with *Orthodontopsis*, so the latter genus is not considered here as an endemic of the Western and Northern Palearctic.

Discussing endemic genera, two more genera are also worth to be mentioned. (1) *Echinodium* has 4 endemic species in Macaronesia, and after huge disjunction 2 endemic species occur in Australia and Oceania. Macaronesian and Australo-Oceanean groups of species are somewhat distinct, and further studies might rise their status to generic, though Churchill (1986) preferred at present to retain them in one genus. (2) A putative endemic genus for the western part of Palearctic is also *Rhynchostegiella*. Now this genus is very heterogenic and certainly needs to be split into several more natural entities. One of them is the group of 6-8 species of Europe, Macaronesia, North Africa and Middle East, most of them are endemic for this area; two species of this group, *R. curviseta* and *R. tenella* were reported from China (Redfearn & al., 1996), but I never

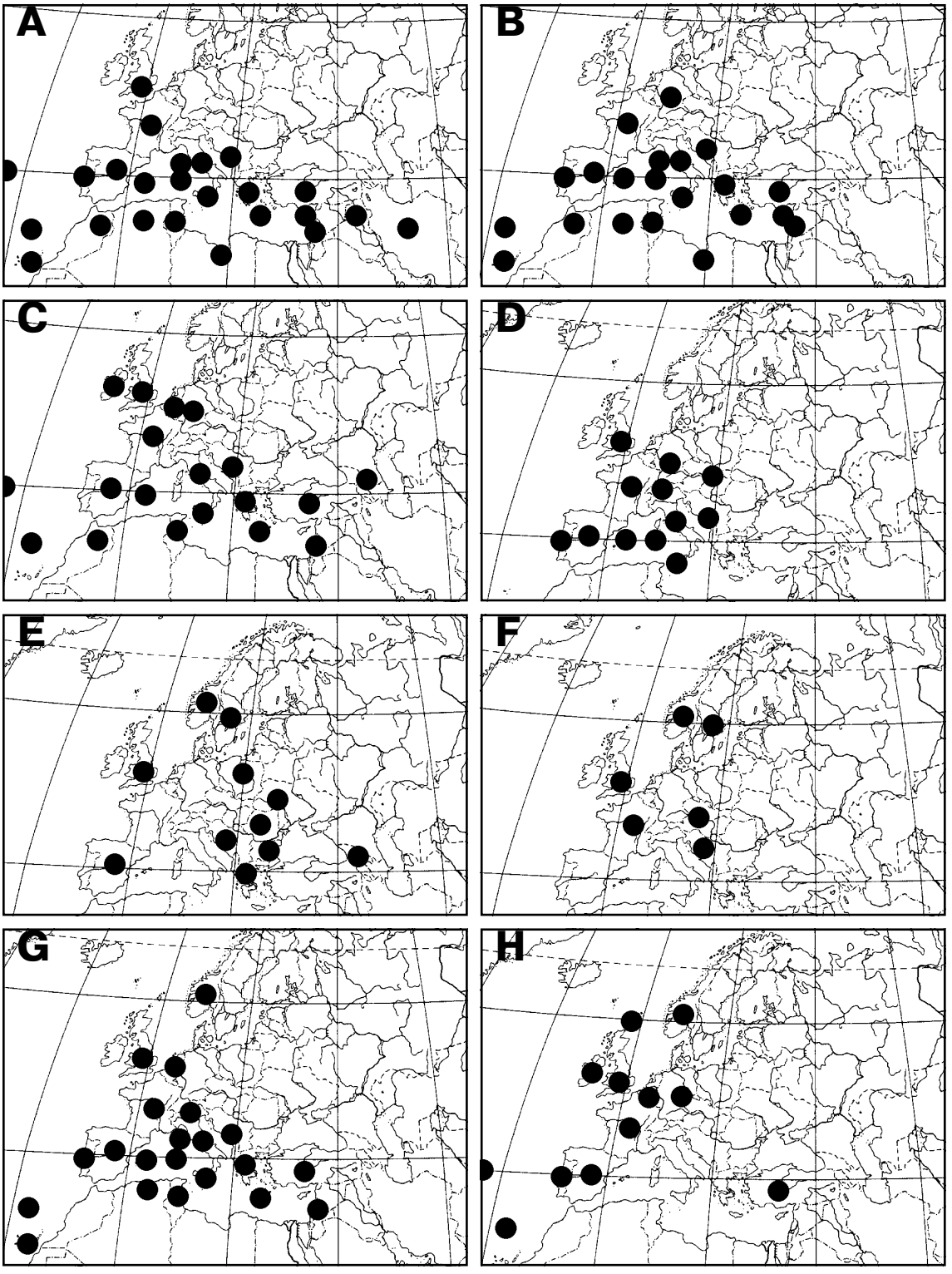

Fig. 9. Distribution of endemic and putatively endemic genera of the western and northern Palearctic: A – *Cheilothela*; B – *Funariella*; C – *Leptobarbula* (+AS3?); D – *Pottiopsis*; E – *Ptychodium*; F – *Trochobryum*; G – *Habrodon* (+Japan?); H – *Hyocomium* (+China?). Mapping is in most cases to a country level.

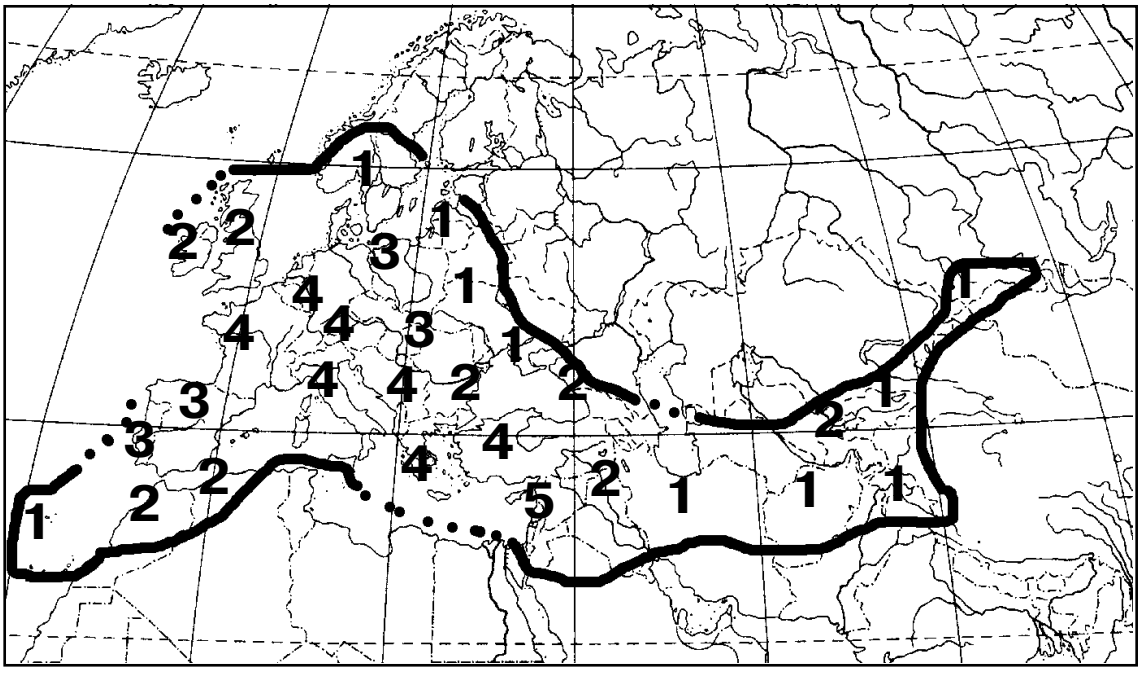

Fig. 10. Distribution of the family Cinclidotaceae with the only genus *Cinclidotus*. Number means the number of species in an individual area.

seen any collection of them from that country and some herbarium collections named so were an erroneous identifications.

The only subendemic family of the Western and Northern Palearctic is Cinclidotaceae (as *Cinclidotus mucronatus* (Brid.) Machado is transferred to the genus *Dialitrichia* which belongs to Pottiaceae (Zander, 1993)). This family has one genus with 8 species, with a record of one species from Kashmir State of India and one species from Xizang Province of China (Fig. 10).

It is important to note, that most of generic endemics of the Western and Northern Palearctis are distributed in the South and West of Europe, i. e. in the area with the high moss species diversity (cf. Figs. 1 and 9).

The above discussed situation with the generic endemism in Western and Northern Palearctic is a little different from that in North America, north of Mexico. The latter area have 12 endemic (+2 nearly endemic) genera (Schofield, 1980, with minor changes). All of them are monotypic, but quite isolated systematically (and well-reputated), and also most of them have a rather wide distribution. This can be explained by a stronger isolation of North America in the past.

It is interesting also, that North American endemics are mostly mesic plants, and more than half of them grow on trunks and logs in forests, and occasionally on rocks; more than half are from Bryales and Leucodontales orders. No one is an epigeic plant of xeric environment, and no one is from Pottiaceae family. Contrary to this, among endemics of the Western and Northern Palearctic are *Cheilothela* (Ditrichaceae, epigeic xerophyte), *Leptobarbula* (Pottiaceae, epilithic xerophyte), *Pottiopsis* (Pottiaceae, on soil and chalk, mesoxerophyte), *Funariella* (Funaricaeae). Note also high percent of endemic species in *Enthostodon* (Table 2), a genus of prinipally xeric environments. These data on endemism confirm the above conclusion (see p. 229) of the more xeric general situation in Europe, than that in North America.

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[1] – after this paper was prepared for publication, *Bardunovia* was found in Yakutia (Ignatov & al., 2001).

Zennoske Iwatsuki, for supplying me with computer version of his checklist of Japan, which was converted and added to my database,to Benito Tan,for supplying me with computer version of the checklist for China and many advices on themanuscri pt,Timo Koponen, for support of my visit to Helsinki where I could find many recent publications to enrich the database. Vladimir Onipchenko (Moscow University) kindly helped with the statistical work. This work was partly supported by the Russian Foundation for Basic Researches, grant 99-04-48194.

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