

THE DATABASE OF THE MOSS FLORA OF RUSSIA  
БАЗА ДАННЫХ “ФЛОРЫ МХОВ РОССИИ”

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Abstract

This publication is to announce the database of the Moss Flora of Russia at <http://arctoa.ru/Flora/basa.php>. It also explains the strategy and approaches so as to be maximally useful for the publication of the Moss Flora of Russia, a six-volume print edition that was started in 2017. The database currently contains over 128 000 records; it is shown to be reasonably complete for illustrating the species distribution within the expanded territory of the country. A number of scripts allow instant comparison of various territories, highlighting hotspots and underexplored areas. Problems of data control and presentation are discussed.

Резюме

В данной статье анонсируется база данных по флоре мхов России, размещенная по адресу <http://arctoa.ru/Flora/basa.php>. В ней также представлены стратегия и подходы к максимально полному ее использованию для подготовки публикации шеститомного печатного издания “Флора мхов России”, которое стартовало в 2017 г. В настоящее время в базе представлено более 128 000 образцов; показано, что уже сейчас распространение видов на территории страны отражается адекватно. Наличие нескольких скриптов позволяет быстро проводить сравнение флор разных территорий, которое выявляет наиболее флористически богатые регионы и “белые пятна” в исследовании флор. Обсуждаются проблемы контроля за внесением информации и ее представлением.

KEYWORDS: database, Bryophyta, Russia, Biogeography, biodiversity.

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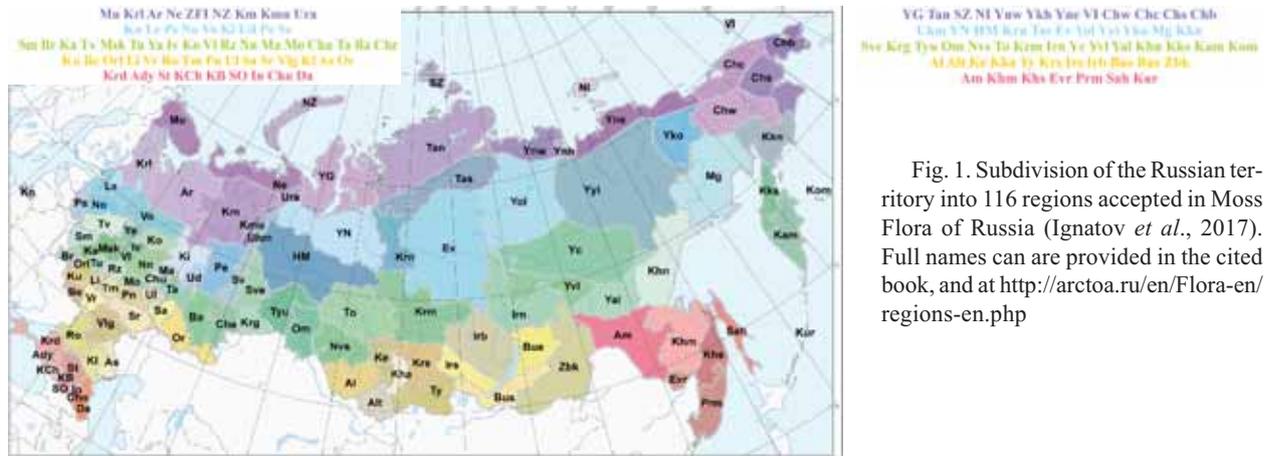


Fig. 1. Subdivision of the Russian territory into 116 regions accepted in Moss Flora of Russia (Ignatov *et al.*, 2017). Full names can be provided in the cited book, and at <http://arctoa.ru/en/Flora-en/regions-en.php>

## INTRODUCTION

The Moss flora of Russia has never been written with a sufficient completeness. The only monograph with morphological descriptions of all species was published by Weinmann (1845), which “Syllabus...” included ca. 300 species, recorded mostly from the surroundings of St.-Petersburg and Moscow, with a few records from the Siberian and Arctic expeditions. Warnstorf (1913, 1914) published a check-list of the moss flora of the Russian Empire, but a considerable part of the records were from outside the present political border of Russia, including the better studied (at that time) Baltic countries, Finland, Georgia in the Caucasus, Middle Asian states, *etc.* A checklist of the territory of the former USSR (Ignatov & Afonina, 1992) and a checklist of East Europe and North Asia (Ignatov, Afonina, Ignatova *et al.*, 2006) compiled available data. These lists included ca. 1050 and 1129 species for the territory of Russia, while at present (the beginning of 2017), the number of species known in Russia approaches 1280. Since 1992, more than 300 species have been added to the Russia moss flora, and over 50 species have been excluded. The exclusions include taxa that were erroneously recorded, or appeared to belong to different taxa in the course of taxonomic revisions (*e.g.*, *Schistidium strictum*, widely reported in most regions of Russia before the revision of the genus by Blom, 1996). The numerous changes mean that there are difficulties in the use of published data, and therefore herbarium specimens appear to be the only solid basis for the verification of species distribution.

The project of the Moss Flora of Russia was started in 2003, as principally a continuation of the Moss Flora of the Middle European Russia, which resulted in a publication of a two volume flora covering 543 species (Ignatov & Ignatova, 2003, 2004). Being partially supported for short-term subprojects by the Russian Academy of Sciences and the Russian Foundation for Basic Researches (mostly for exploration of certain territories and taxonomic revisions of a certain groups), the project, however, necessitated accumulating and combining data from the main Russian herbaria in a reasonably short time.

Up to 2017, the beginning of the publication of the Moss flora of Russia (Ignatov *et al.*, 2017), the database reached 128,000 records, which can be estimated as between 10 and 20% of all moss specimens from Russia in all herbaria. Thus, it seems an appropriate time for announcing the database, presenting its opportunities, advantages and disadvantages.

The main goal was to make the database easy to populate and easy to correct/update/supplement (*e.g.*, with geositional information, if it was originally lacking). Another goal was to make the database useful for various purposes in biodiversity studies.

### 1. GENERAL INFORMATION

The database is made in the Firebird database management system for the OS FreeBSD, and is kept in at least two servers in the Lebedev Institute of Physics and the Tsitsin Main Botanical Garden of the Russian Academy of Sciences. The common entrance to the database is from <http://arctoa.ru/Flora/basa.php>. There are general comments for its usage at this homepage. Everyone may enter under the common login: “moss” and password “moss”. The special authorization with personal login/password provides additional opportunities for users. A personal login/password can be requested from [areoana@list.ru](mailto:areoana@list.ru) with subject authorization. The general supervision of the database is conducted by Ivanov, the script upgrading is a responsibility of Ivanov and Kolesnikova, and the rights for insertion and correction of data are delegated to several bryologists (Baisheva, Ignatov, Kozhin, Pisarenko) who check, insert and update data obtained and preliminarily prepared by other authors of this paper, also with the help of other colleagues, supplying smaller amounts of data. All the data from the New Bryophyte Record section published in the journal *Arctoa* are also included in the database.

### 2. THE DATABASE STRUCTURE

Fields of the database are rather standard (Table 1). Only four of them are mandatory: (2.1) species, (2.2) MFR region, (2.3) herbarium, and (2.4) the source of geosition information.

Table 1. List of fields in the database – Список полей базы.

|  |
|--|
| key_id – Номер записи                              |
| Species – Вид                                      |
| Sensu_lato – Статус_понимания_вида                 |
| Intraspecific_taxa – Внутривидовой_таксон          |
| MFR_region – Регион_ФМР                            |
| RF_region_label_written                            |
| Locality_general – Местонахождение общее           |
| Locality_exact – Местонахождение точное            |
| label_in_English                                   |
| Habitat – Местообитание                            |
| Altitude – Высота_над_у.м.                         |
| Latitude – Широта (как на этикетке)                |
| Longitude – Долгота (как на этикетке)              |
| Latitude_r – Широта, в виде десятичной дроби       |
| Longitude_r – Долгота, в виде десятичной дроби     |
| Coordinate_accuracy – Точность геопозиционирования |
| Geoposition_source – Источник координат            |
| Altitudinal_belt – Высотный пояс                   |
| Collection_date – Дата сбора                       |
| Collector(s) – Коллектор(ы)                        |
| Collector_number – Коллекторский номер             |
| Identified_by – Определил                          |
| Comments – Комментарий                             |
| Sporophyte – Спорофит                              |
| Admixture – Примеси                                |
| Herbarium – Гербарий                               |
| Herbarium_number – Гербарный номер                 |
| Confirmed_by – Подтверждено                        |
| identification_history – прежние определения       |
| Cited in literature – Опубликовано в               |
| was_changed – изменения этикетки                   |
| DNA data – ДНК данные                              |
| Type status – Типовой образец                      |

2.1. The species list is fixed according to the recent checklist (Ignatov *et al.*, 2006) and supplemented from the subsequent taxonomic literature. Alternative names (synonyms of common use, *e.g.* *Brachythecium velutinum* / *Brachytheciastrum velutinum*; *Racomitrium canescens* / *Niphotrichum canescens*) appear in the drop-down menu of the query forms, but the query report uses the nomenclature of the main list only.

2.2. The territory of Russia is subdivided into the 116 regions accepted for the “Moss Flora of Russia” (Fig. 1). Such subdivision provides the possibility of showing species distribution by abbreviations in the country where

political units differ in size by up to 1000 times. Also, this subdivision, we hope, will encourage researchers to concentrate on under-explored regions, filling the gaps, which is an important aim of the current period of the Russian moss flora exploration.

2.3. Herbaria are shown by Index Herbariorum acronyms, or, if unavailable, as an institutional or personal collection.

2.4. The source of coordinates implies four variants: by GPS by collector; by map by collector, by map by somebody other than collector (based usually on locality name), and “unknown”. This field was absent originally and added only recently; thus for old records the source of information is not always definite and is marked as “unknown” until more definite information of the source of information and accuracy can be supplied.

### 3. MAIN QUERY FORMS

The “Herbarium specimens” query selects specimen data by one of three query forms of different levels. By default, the level is “short”, for simple questions (presence of a species in a region and names of localities). For additional information, select Basic and Advanced query forms, where more fields appear. Ticked boxes will be shown in the report, and on the right will be a column with the number of specimens relevant to the level: for example, when only the field ‘region’ is selected, then column on the right will show how many specimens are from each region in the database. The more boxes are ticked, the more information will be selected. Templates for search are filled manually, except the genus or species name and regions of the Moss Flora of Russia (MFR), which appear in drop-down menus. Selection can be done for all species of the genus as well as for individual species. As it is explained above, the species list contains the alternative names of common use, including synonyms (those are marked by one asterisk). More explanation about alternative names is given below in Section 6: Updating and reidentification. The drop-down menu for MFR regions shows either an abbreviation (by default) or the full name (choose code/full name) in a box nearby.

Table 2. Main scripts and their functions, available for non-registered users.

| Function   | Функция   | Script                         |
|--|---|--------------------------------|
| Herbarium specimens of Russian mosses  | Гербарные образцы Флоры мхов России   | select_6.pl                    |
| Herbarium specimens of Russian mosses selected by ranges of latitude, longitude, altitude, and collection date | Гербарные образцы Флоры мхов России с выбором по диапазонам значений широты, долготы, высоты над ур.м. и даты сбора | select_diapason.pl             |
| Maps of mosses in Russia (for one species)   | Карты распространения видов (для одного вида)   | maps_sp1.pl                    |
| Multi-species maps of Russian mosses with selected marks   | Карты распространения для 1-6 видов, с выбором символов   | maps_select_multi.pl           |
| Compare regions using correlation coefficient  | Сравнение регионов при помощи коэффициента корреляции   | compare_regions.pl             |
| Species diversity by squares of coordinates  | Число видов по квадратам координатной сетки   | species_per_square.pl          |
| Species diversity by squares of coordinates upon map   | Число видов по квадратам координатной сетки на основе карты   | species_per_square_maps_new.pl |
| Report including species by regions  | Отчет о количестве видов в регионах   | stat_species.pl                |

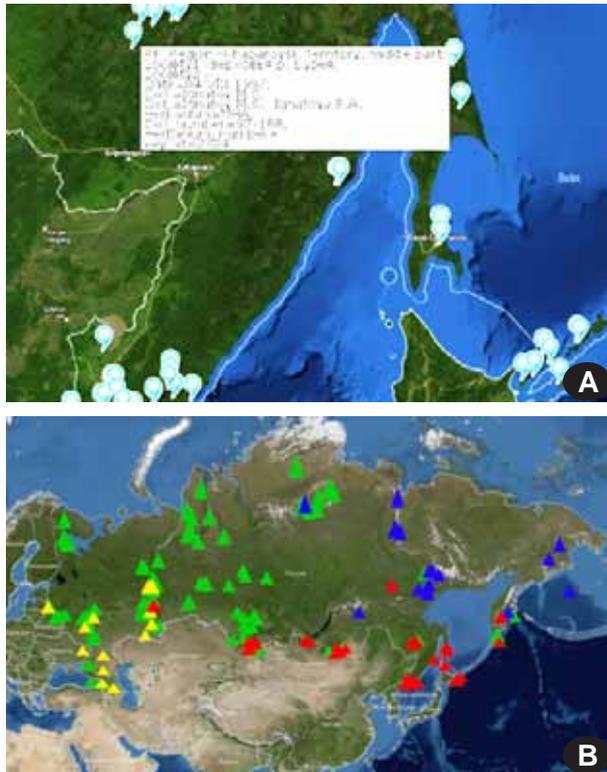


Fig. 2. Single (A) and multi (B) map options of the database. “B” illustrates distribution of four *Brachythecium* species: *B. mildeanum* (green), *B. glareosum* (yellow), *B. buchananii* (red) and *B. boreale* (blue), showing different biogeographical patterns.

The simplest, quickest and thus most widely used option is “Maps of mosses in Russia”. A map will be generated for one species after its name is selected from the drop-down menu (the dots for records “sensu lato” and “cf” will be included as default: for their exclusion tick the box “excluding sl.” and “excluding “cf”). On these maps for single species, clicking on any dot provides essential data from the specimen label (Fig. 2A), while multi-species maps lack this option.

The multi-species map option allows combining on one map the distribution of one to six species. In this case, the user may select the colour, symbol and size of symbol for each individual species (Fig. 2B).

#### 5. DATA INSERTION

Data insertion is processed by few authorized database managers. Excel (\*.xls) files with field names are sufficient for insertion into the database. Mandatory fields are checked by scripts, and if the species name or the name of the region does not fit the lists of species/regions in the database, then the error is highlighted in the returned file, which has to be uploaded again after correction(s). General checking of inserted information is monitored by the database managers.

If the species is new for the country, then a separate script is required, which adds the name to the species list.

This simple way to fill the database with files containing usually 100–1000(–2000) labels facilitated the accumulation of data from various research projects; only minor reformatting is usually needed for uploading such files to the database.

#### 6. UPDATING AND REIDENTIFICATION

Data updating can be done by a few authorized database managers.

There are several options which can be used for the correction of single fields in one particular label, or the “change all” option can be used. The latter option is useful, *e.g.*, when coordinates are added to the locality which lacks them in the original label. In this case, information about the status of these coordinates is provided in the field of “Coordinates\_accuracy” and “Source of geoposition”.

Reidentification of misidentified specimens can be done in the same way as any other simple updating and can be done for one or more labels. Previous identifications can be seen either (1) for individual specimens, or (2) appear in query if the box “previous identification” is marked in the advanced query form.

There are, however, some more complicated cases which are related to changes in taxonomic concepts of the species. For example, if the genus undergoes a revi-

The database allows a comparison of species composition between two regions. For this mark “compare two selections” and choose regions. Option “AND” shows species known in both X and Y regions; “xOR” shows species occurring in at least one of them.

Template matching possibilities include: 1) exact match; 2) subfield exact match; and 3) regular expression. Subfield exact match is slower than exact match, but allows selection by partial text, which is useful when the spelling is forgotten, or for selecting, *e.g.*, “tree” and “trees”. The regular expression option requires a basic knowledge (*e.g.*, from (<http://www.regular-expressions.info/> or <http://www.cs.tut.fi/~jkorpela/perl/regexp.html>), but it provides a lot of opportunities for more complicated questions. For example, MHA|LE|MW in the field Herbarium will select specimens from either MHA or LE or MW herbaria; ^X will select all data from the corresponding field starting with X (for example, ^5 in the latitude field will select all values from 50 to 59 degrees of latitude); rock[sy] matches “rocks” and “rocky”; ^\s matches blank fields.

A special script has to be run if the specimen selection is needed for the certain interval in ranges of latitude, longitude, altitude, or collection dates. It may take more time, compared to the main script.

#### 4. MAPS FORMS

The records with available latitude and longitude can be shown in maps. Maps are based on the yandex\_map facility and have a standard zoom in and zoom out option, showing maps, schemes, or satellite images of standard quality.

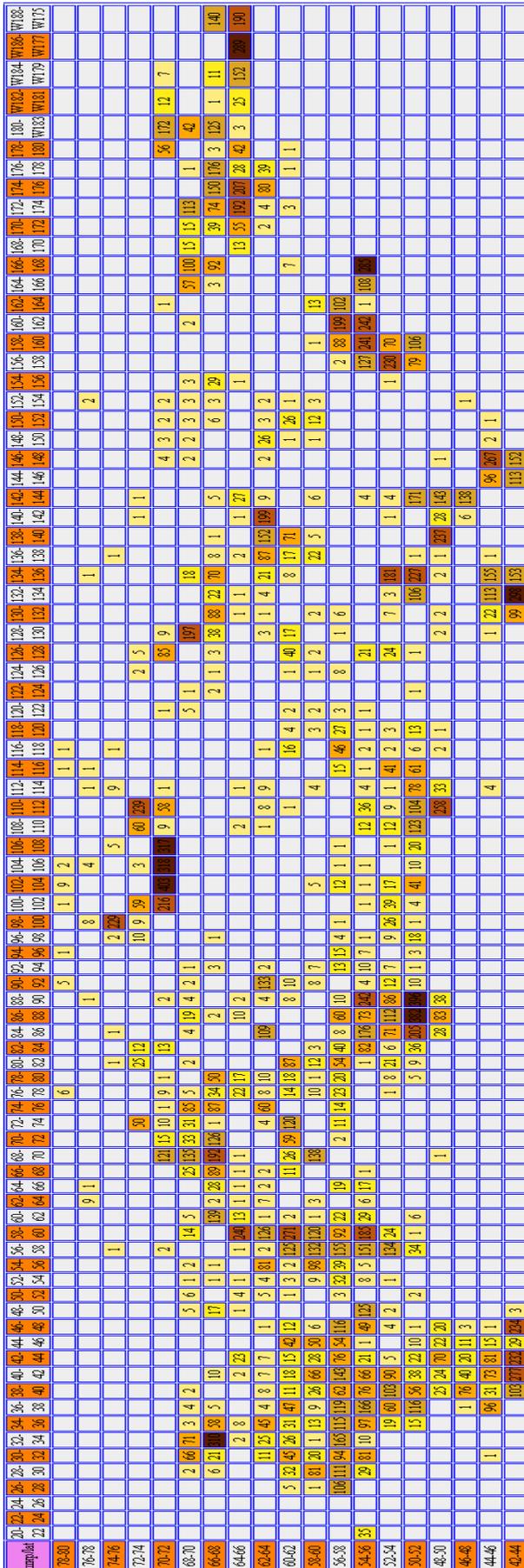


Fig. 3. The number of species in grid squares 2°x2° (roughly 100 x 200 km), for the area from 42° to 80°N and 20°E to 170°W, showing the level of exploration of the territory of Russia (cf. Fig. 7), where the country outline is shown. Note there are rather few squares with more than 200 species. Also note that the specimens without coordinates are not shown in this map.

sion with splitting, at least one species usually has more than one sense: sensu stricto (s. str.) and sensu lato (s.l.). Usually the scheme is as follows: A s.l. becomes A s.str. + B + C, etc. This ideal scheme, however, almost never happens. In practice, not all specimens of A s.l. can be sorted among A s.str. or B or C, and usually some specimens remain under A s.l. For example, *Ulota crispata* (Hedw.) Brid. s.l. was split into *U. crispata* s.str., *U. intermedia* Schimp. and *U. crispata* Bruch (Caparrós et al., 2016), and since a narrow species concept is applied, either (1) reidentification (i.e. applying a different name), or (2) confirming of sensu stricto status takes place. Identification of these species is based on sporophyte morphology, but a number of specimens of *Ulota* lack sporophytes. Bryologists usually avoid collecting Orthotrichaceae without sporophytes due to difficulties with identification, but *Ulota crispata* s.l. is an exception: it has conspicuously crispate leaves making it easy to recognize (as it was before splitting), thus it was often collected in the sterile state. After the splitting of *U. crispata* s.l., such specimens became indistinguishable, at least by morphology. We have to consider this situation properly in order to avoid mapping old identifications, which were correct before the taxonomic revision, but became vague afterwards.

This situation explains the purpose of the field called “Sensu lato”. When the revision of herbarium collections based on a new approach (e.g., for *Ulota*) starts, all specimens identified previously as *Ulota crispata* would be supplied with the mark “sl” in the field “Sensu lato”. Reidentification of a specimen, as well as confirmation of its status, results in the deletion of the “sl” mark, while if the record remains unrevised, it retains the “sl” mark. Using queries and making maps of species distribution, one may tick or not tick the box “excluding sl”.

7. CONTRIBUTIONS TO THE DATABASE

In the beginning of 2017, the database was based on contributions from the following herbaria (numbers indicate thousands of included specimens): MHA – 32, KPABG – 23, LE – 21, MW – 13, SASY – 7, PPU – 4, NSK – 2.7, TVBG – 2.4, KAND – 2.2, CSR – 1.7, S – 1.3, UFA – 1.2.

In June 2017, 128,369 records were in the database. However, this figure is difficult to evaluate. Does it represent the whole country sufficiently evenly, or some regions have very good representation, whereas many others remain blank? The map in Fig. 3 shows that unexplored areas constitute about half of the 2°x2° grid squares. Thus, the criteria for representativeness should be different from just the number of recorded specimens.

Fig. 4. Numer of records (left) and species (right) in better studied regions of the Moss Flora of Russia.

| Region | Records | Region | Number of species |
|--------|---------|--------|-------------------|
| Mu     | 26888   |        |                   |
| Alt    | 7545    |        |                   |
| Yyi    | 5307    |        |                   |
| Tas    | 4748    | Tas    | 552               |
| Msk    | 3669    | Kam    | 524               |
| Pe     | 3665    | Mu     | 486               |
| Krd    | 3560    | Yyi    | 423               |
| Tv     | 3095    | Chi    | 390               |
| Prm    | 2591    | Pe     | 387               |
| Chb    | 2532    | Krd    | 380               |
| Khm    | 2376    | Prm    | 378               |
| Kam    | 2341    | KCh    | 367               |
| Le     | 2259    | Kur    | 348               |
| Chi    | 2157    | Da     | 328               |
| Kur    | 2080    | Ke     | 312               |
| YG     | 2069    | Kom    | 312               |
| Ba     | 2037    | Ba     | 311               |
| KCh    | 2024    | Ady    | 296               |
| Da     | 2014    | YG     | 295               |
| Ar     | 1766    | Sah    | 293               |
| Krl    | 1635    | Khm    | 287               |
| Uhm    | 1575    | Tv     | 280               |
| Iv     | 1468    | Tan    | 270               |
| Chs    | 1436    | Msk    | 260               |
| Yal    | 1431    | Krl    | 259               |
| Km     | 1312    | Yal    | 259               |
| Ps     | 1285    | Khs    | 247               |
| VI     | 1232    | KB     | 244               |
| Ady    | 1226    | Uhm    | 243               |
| Tan    | 1208    | Le     | 232               |
| Khs    | 1173    | Nvs    | 218               |
| Kom    | 1163    | Ar     | 215               |
| Ke     | 1109    | Ps     | 204               |
| HM     | 1082    |        |                   |
| Sah    | 1064    |        |                   |

The data in Table 4 illustrate the distribution of records by region of the MFR (cf. Fig. 1): over 1000 specimens are databased for 35 regions; there are more than 100 species in 79 regions; and more than 200 species in 31 regions (Table 4, Fig. 4).

However, it would be easier to use a “species-region” as a universal criterion: the sum of the numbers of regions where each species occurs. The “species-region” value in June 2017 was 19,011. Is this low or high? If we imagine that all species in the country occur in all regions, then the number of records representing all species from all regions by one specimen would be  $1280 \times 116 = 148,480$  “species-regions”. Assuming however, that many species are limited to one or a few areas and also expecting the hyperbolic distribution, similar to that shown in Fig. 4, the real potential number of “species-regions” for Russia can be expected to be around 30,000–33,000, *i.e.*, with the average number of species in a region being 259–285. There are, of course, three known regions (and potentially a few more) with over 500 spe-

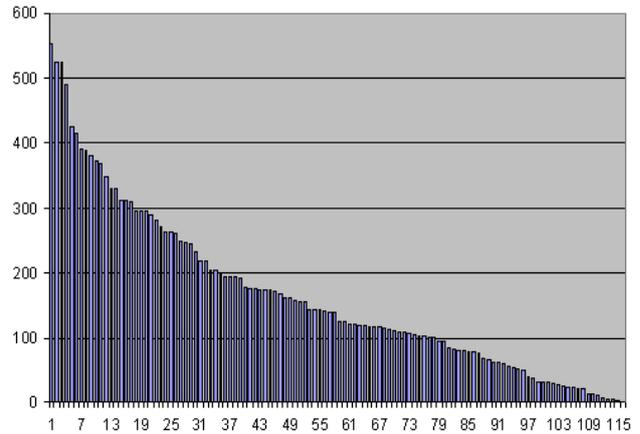


Fig. 4. Distribution of the number of species (axe Y) in 116 regions of the Moss Flora of Russia.

cies in Russia, but, at the same time, a number of a relatively well studied xeric regions have fewer than 150 species. High Arctic regions have a diversity only slightly exceeding 100. Most relatively well studied provinces in the Central European Russia have fewer than 250 species.

Thus, if our estimation of 30,000–33,000 potential “species-regions” in Russia is correct, then the 19,011 “species-regions” available in the database represent more than half and perhaps close to two-thirds of the diversity of mosses in Russia by regions, allowing a proper representation of species distribution in the Moss Flora of Russia.

Of course, the immediate aim, to collect data for regions, is not the final one, and a further step should be coverage by  $5^\circ \times 5^\circ$  grid squares, which is still very gappy (cf. Fig. 6, remembering that it reflects only specimens with geospatial data).

## 8. BIODIVERSITY STUDIES

The data from the database can be analyzed by a simple instant script (Fig. 5) based on Jacqard index (Jacqard, 1901) of inter-regional similarity. After the region selection (Fig. 5A,B), one obtains a table (species occurrence in selected regions – Fig. 5C), complete matrix (Fig. 5D) which can be analyzed further with statistical methods, and a visualization of similarities by Terentiev (1953)’ correlation pleyades (Fig. 5E). Terentiev (1953)’ correlation pleyades often show the similarity between regions by thickness of lines, although they are somewhat dependent on the completeness of the studied flora: poorly studied areas (of paler colour in map in Fig. 5A) are characterized by slighter similarity.

Another script provides distribution of species by grid squares with the selected sides of quasi-rectangles (in fact trapezoids) with the chosen sides of latitude and longitudes in degrees (separately for latitude or longitude), the grid scale is, in principal, unlimited (Fig. 6A). However an attempt to make a table with more than 10,000 cells may take a very long time, so the grid scale has to be chosen to be reasonable and corresponding to the area

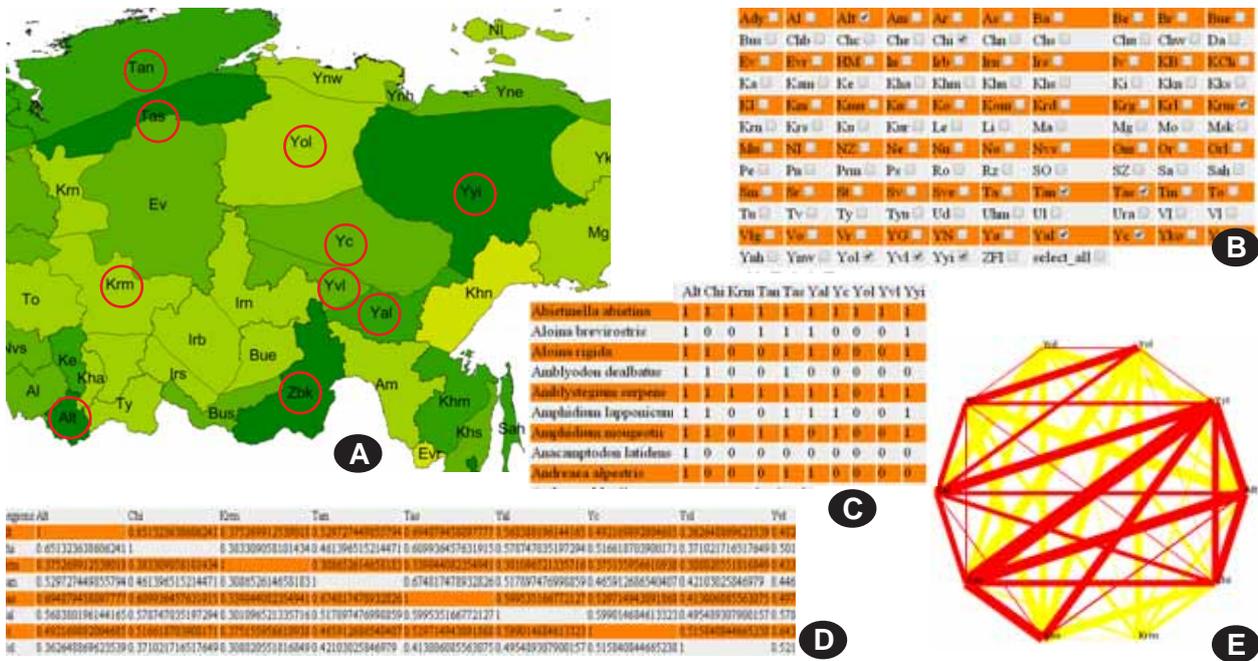


Fig. 5. Instant script “Compare regions using correlation coefficient” with example of ten Siberian regions: A: map of regions to compare; B: selecting regions; C: table of relevant species; D: datamatrix of correlation coefficients; E: graph.

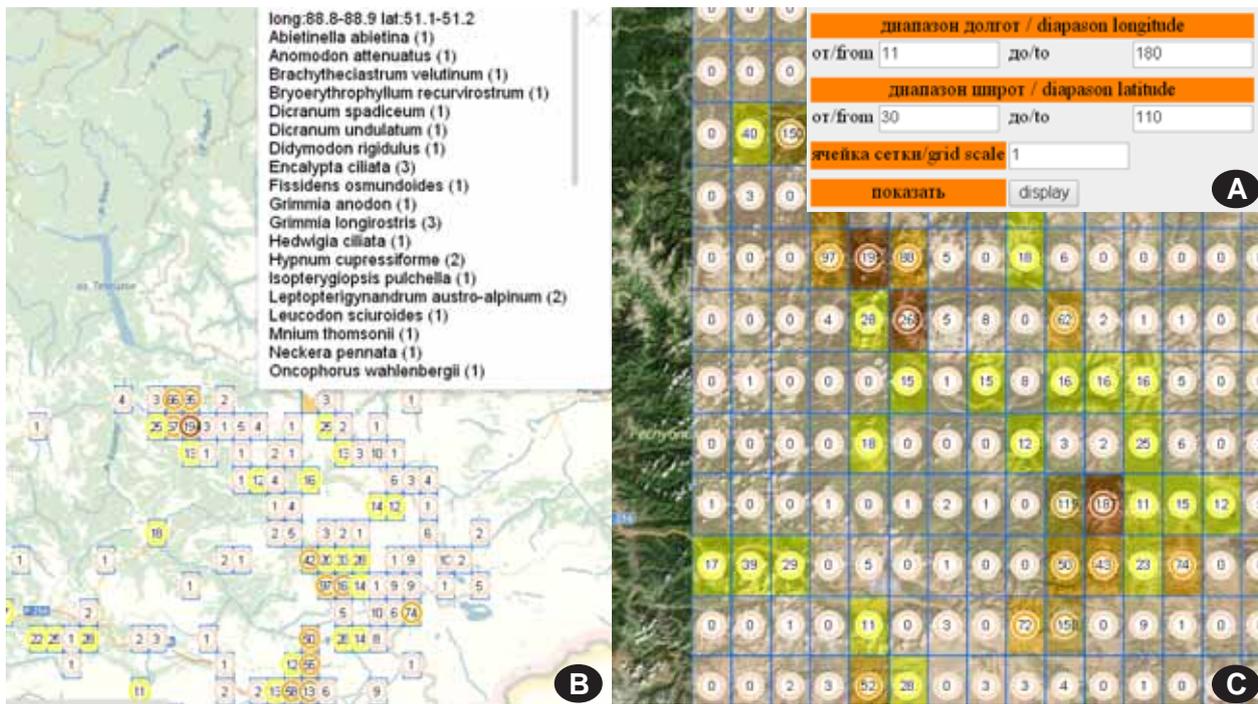
of interest, which is also selected by inserting limits of latitude and longitude (Fig. 6A).

The same kinds of grid squares can be shown upon the maps (Fig. 6B–C), and these also have an option to show all species occurring in the given grid square by clicking (Fig. 6B). This option may be applied to local studies, as well as to all-Russian studies (Figs.6–7).

Among others, Fig. 7 illustrates a principal coincidence in distribution of high biodiversity areas by two methods: in maps by regions and in maps by grid squares. It means that ca. 60% of specimens that have coordinate data (shown in Fig. 7B, squares) represent the full diversity (shown in Fig. 6C) quite adequately.

To assess additionally the completeness of the data

Fig. 6. Distribution of the moss species richness in a local area (part of Altai) by selecting 1°x1° and longitude and latitude diapason (A). Variants of maps are shown in B and C. Clicking the cell with number of species gives the species list for that area (with number of specimens of each species).



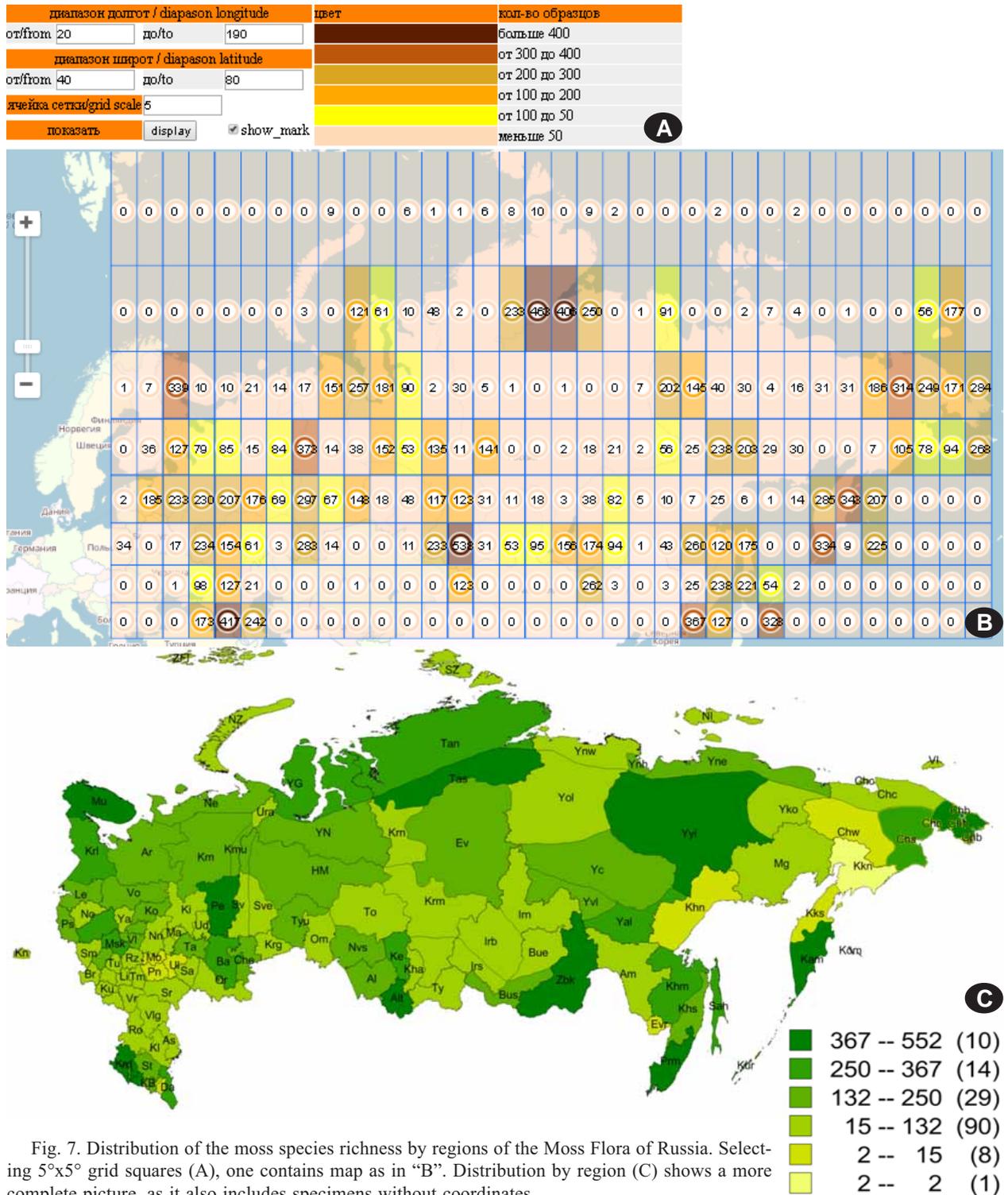
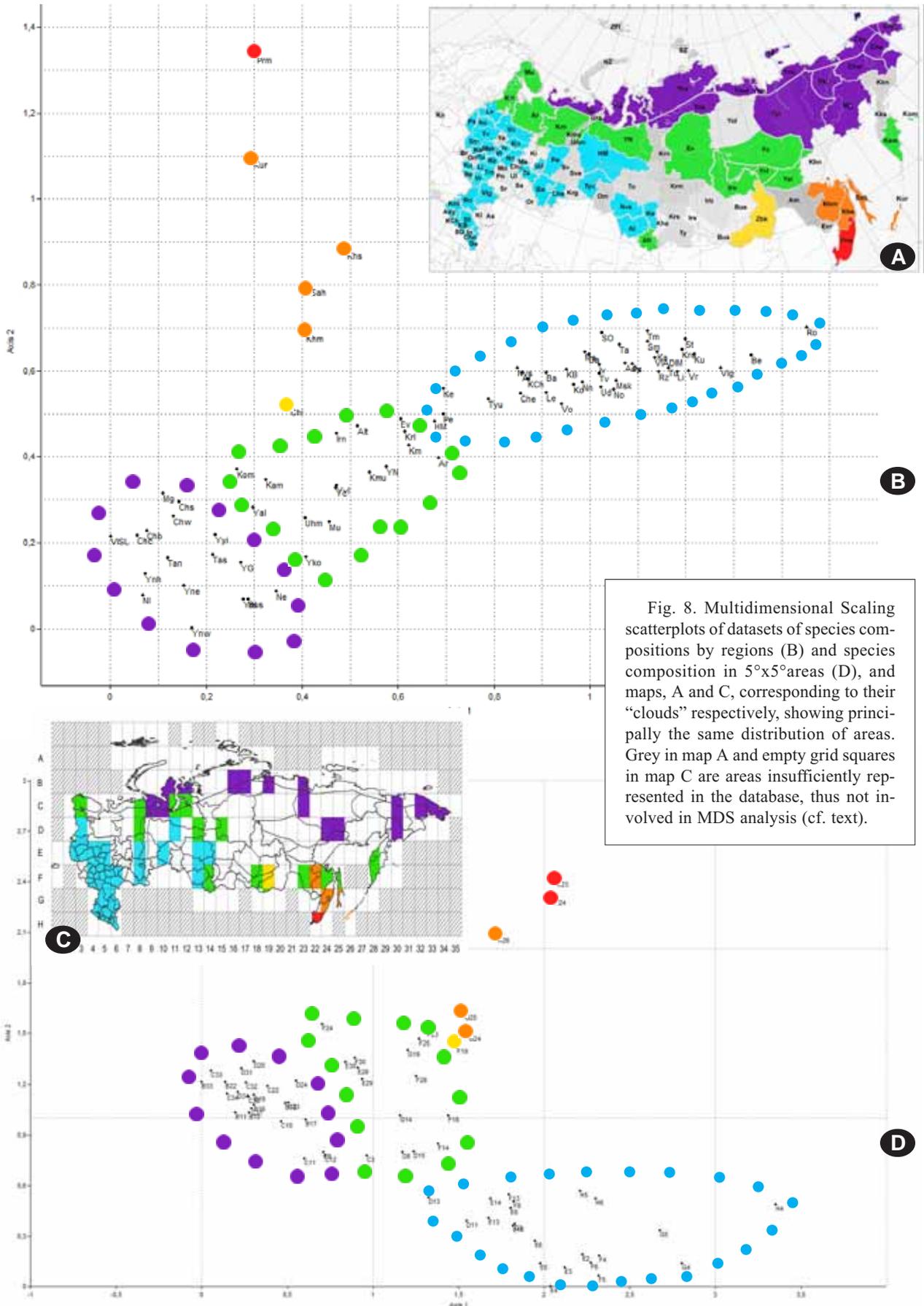


Fig. 7. Distribution of the moss species richness by regions of the Moss Flora of Russia. Selecting 5°x5° grid squares (A), one contains map as in "B". Distribution by region (C) shows a more complete picture, as it also includes specimens without coordinates.

already in the database, we ran multivariate analyzes on two datasets: (1) the binary matrix of the 1188 species distribution through 116 MFR regions, and (2) the binary matrix of the same number of species in 360 grid squares of 5° latitude x 5° longitude.

For the final analysis, we omitted poorly studied regions, where the species number was lower than 100 species, with a few exceptions for lowland xeric areas with

overall low diversity. So, for the first, *i.e.*, regional analysis, data from 79 regions (out of 116) were included. For the second analysis, the territory of Russia is divided into 195 5°x5° grid squares; among them, 167 have at least one record in the database, but only 66 could be selected for further analysis on the same criteria (either >100 species per 5°x5° area, or a xeric region with a very poor flora).



Selected regions and grid squares were compared using multidimensional Scaling (MDS) and Detrended Correspondence Analysis (DCA), suggested as suitable to find the main factors or gradients in large, species-rich but usually sparse data matrices (Hill & Gauch, 1980). All analyses were performed using Past ver. 2.17 (Hammer *et al.*, 2001).

Two scatter plots from MDS show similar trends in the overall diversity distribution, rather well corresponding to the main biogeographic zones and pointing on highly specific moss flora of the Russian Far East (Fig. 8). They are based on data for regions (Fig. 7A) and data for 5°x5° grid squares (Fig. 7B), the latter not including specimens without coordinates. The fact that both scatterplots are principally similar in co-arrangement of regions ensure that the amount of data with coordinates evenly represents the species diversity in Russia and is sufficient for at least a general biogeographical estimations. DCA analysis (not shown here) gave an essentially similar results. They will be discussed in detail in a separate paper.

\* \* \*

We are aware that the database in its present state is far from ideal, and data collected already include mistakes of all sorts. Therefore, all notes on mistakes in the program and data are highly appreciated and these mistakes will be corrected as soon as possible.

Individual mistakes in data can be sent for correction in the Excel file downloaded from the database (tick box “downloads file” in advanced query form), so it will include (1) keyid (2) field(s) to correct [no other fields are needed], and the point that is to be corrected.

For supplying coordinates to the labels which lack them, please indicate the same: (1) keyid; (2) longitude and latitude in any format, BUT note that a dot or a comma must appear for the first time at the point where decimal numerals start.

For repeated mistakes you may indicate simply:

(1) field (2) change XXXXX into YYYYYY.

All corrections should be addressed to the database managers using the address: areoana@list.ru.

The usage of the database is free. All references to the database data require citation of this article.

#### ACKNOWLEDGEMENTS

We are grateful to Nick Hodgetts for the English correction and valuable comments on the manuscript.

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