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Research

Taxon-level assessment of the data collection quality in *Atlas Florae Europaeae*: insights from the case of *Rosa* (Rosaceae) in Eastern Europe

Anatoliy A. Khapugin, Anna Sołtys-Lelek, Nikolay M. Fedoronchuk, Albert A. Muldashev, Vladimir A. Agafonov, Elena S. Kazmina, Vladimir M. Vasjukov, Olga G. Baranova, Irina O. Buzunova[†], Lyudmila V. Teteryuk, Dmitriy V. Dubovik, Zigmantas Gudžinskas, Toomas Kukk, Alexey V. Kravchenko, Andrey V. Yena, Mikhail N. Kozhin and Alexander N. Sennikov

A. A. Khapugin (https://orcid.org/0000-0002-6059-2779), Tyumen State Univ., Tyumen, Russia, and: Joint Directorate of the Mordovia State Nature Reserve and National Park 'Smolny', Saransk, Russia. – A. Sołtys-Lelek, Ojców National Park, Poland. – N. M. Fedoronchuk, Dept of Systematics and Floristics of Vascular Plants, Kholodny Inst. of Botany of the National Academy of Sciences of Ukraine, Kyiv, Ukraine. – A. A. Muldashev, Inst. of Biology, Ufa Research Centre RAS, Ufa, Russia. – V. A. Agafonov and E. S. Kazmina, Dept of Botany and Mycology, Voronezh State Univ., Voronezh, Russia. – V. M. Vasjukov, Inst. of Ecology the Volga River Basin of RAS, Togliatti, Russia. – O. G. Baranova, Botanical Garden, Komarov Botanical Inst. of Russian Academy of Sciences, St Petersburg, Russia. – I. O. Buzunova and A. N. Sennikov (https://orcid.org/0000-0001-6664-7657) ✉ (alexander.sennikov@helsinki.fi), Herbarium, Komarov Botanical Inst. of Russian Academy of Sciences, St Petersburg, Russia. ANS also at: Botanical Museum, Finnish Museum of Natural History, Univ. of Helsinki, Finland. – L. V. Teteryuk, Inst. of Biology, Komi Research Center, Ural Branch, RAS, Syktyvkar, Russia. – D. V. Dubovik, Laboratory of Flora and Plant Systematics, Inst. of Experimental Botany of the National Academy of Sciences of Belarus, Minsk, Belarus. – Z. Gudžinskas, Laboratory of Flora and Geobotany, Inst. of Botany, Nature Research Centre, Vilnius, Lithuania. – T. Kukk, Dept of Botany, Inst. of Agricultural and Environmental Sciences, Estonian Univ. of Life Sciences, Tartu, Estonia. – A. V. Kravchenko, Laboratory for Landscape Ecology and Forest Ecosystems Protection, Forest Research Inst. of Karelian Research Centre, Russian Academy of Sciences, Petrozavodsk, Russia. – A. V. Yena, Academy of Agrotechnology, Crimean Federal Univ., Simferopol, Russia. – M. N. Kozhin, Dept of Ecology and Plant Geography, Biological Faculty, Lomonosov Moscow State Univ., Moscow, Russia, and: Avrorin Polar-Alpine Botanical Garden-Inst. of Kola Research Centre of Russian Academy of Sciences, Apatity, Murmansk Region, Russia.

By the method of data re-collection and re-assessment, we here test the completeness of distribution areas of the species and species aggregates of *Rosa* in Eastern Europe as mapped in volume 13 of *Atlas Florae Europaeae* (AFE), and discuss insights into the issues connected with the data. We found many new occurrences which are additions to the published maps: 1068 records of species and 570 records of species aggregates. The new occurrences are listed with references to the sources, and the updated AFE maps are provided. The greatest increase by new native occurrences was revealed for the species that are widespread or taxonomically complicated, and by new alien occurrences for the species that currently expand their secondary distribution areas. The mapping work published in 2004 is considered good, with minor omissions caused by possible oversights and incomplete sampling. The majority of new additions originated in the period after the original data collection. Nearly the same amount of new data originated from larger and smaller herbarium collections, underlining the value of small collections for chorological studies. We found that only ca 20% of new records based on herbarium specimens have been published, thus highlighting the need for data papers for publication of distributional data. The greatest increase by new records based on herbarium specimens was found for insufficiently studied territories (Belarus, central, northern and eastern parts of Russia), whereas the same level of increase for the territories with reasonably good coverage (Latvia) was achieved by observations. We

conclude that the overall sparsity of published records in Eastern Europe is caused by a lower level of data collection rather than by poor data availability, and that floristic surveys based on herbarium specimens cannot compete in speed and density of records with observation-based surveys, which may become the main source of distributional information in the future.

Introduction

Atlas Florae Europaeae (AFE) is an ongoing project on large-scale grid mapping of vascular plants, which aims at compiling distribution maps of native and established alien occurrences of all vascular plants in Europe based on the UTM grid with a cell size of approx. 50 × 50 km (<www.luomus.fi/en/atlas-florae-europaeae-afe-distribution-vascular-plants-europe>). Its launch dated back to the 1960s when this project was designed as a technical complement to *Flora Europaea* but also served as a tool for taxonomic and nomenclatural updates and improvements of the distributional data (Suominen 1973). The work is based on a collective effort of many botanists from all countries of Europe; the collected information is assembled and processed by the Secretariat of the *Committee for Mapping the Flora of Europe* in Helsinki.

With completion of volume 17, which included the most tricky apomictic genus *Sorbus* L. s.l. (Kurtto et al. 2018), AFE finally embraced the taxonomic data on the European Rosaceae Juss., which were originally published in volume 2 of *Flora Europaea* (Tutin et al. 1968). The mapping of this large family, which required extensive taxonomic rearrangements and nomenclatural updates in some groups (e.g. *Sorbus* s.l.; Sennikov and Kurtto 2017), lasted for over 15 years and resulted in five bulky volumes (Kurtto et al. 2004, 2007, 2010, 2013, 2018). To date, the project has covered ca 25% of the European vascular plant flora.

Due to the current demand for digital availability of biodiversity data and the high speed of their mobilisation (La Salle et al. 2016, Nelson and Ellis 2018, 2019), data quality of large datasets provided by global aggregators has become a serious issue (Franz and Sterner 2018). Most notably, the lack of high-quality identifications, precise georeferencing and availability of high-quality and updated taxonomic treatments have been stressed (Soberón and Peterson 2004, Crisci et al. 2020). The issue of completeness and accuracy of distributional data in biodiversity resources and mapping projects has recently been demonstrated in several studies (Kalwij et al. 2014, Meyer et al. 2015, Serra-Diaz et al. 2017).

Sampling bias in distributional surveys may be difficult to assess because of many reasons affecting the data (Rich and Woodruff 1992). It has been known for a long time that the distributional data in AFE may be geographically biased due to various data collection practices in the different countries and due to the limited availability of distributional data from some parts of Europe and certain periods (Finnie et al. 2007). Kalwij et al. (2014) compared the data available from AFE and the distribution maps in the *Atlas of North European Vascular Plants North of the Tropic of Cancer* (Hultén and Fries 1986); they found that the density of the distributional data in AFE is significantly lower in Eastern Europe (especially in Belarus, Russia and Ukraine: Lahti and Lampinen 1999) and south-eastern parts of Europe (especially in the former Yugoslavia: Uotila 2017; and in Romania: Finnie et al. 2007), and some discontinuous gradients on the AFE species richness map are associated with political boundaries. The incomplete character of data collection in Eastern Europe is very complex and varying with time; thus, significant improvements were made when, step by step, extra collaborators were added with responsibility for smaller territories (Uotila 2003). Due to the stronger sampling bias in Eastern Europe, this territory was sometimes a priori excluded from analytic studies based on the AFE dataset (Heikinheimo et al. 2012). In contrast, the data from West European countries, especially from Northern and Central Europe and the Baltic countries, has been considered highly reliable and unproblematic (Kalwij et al. 2014).

In this study, we decided to test the level of and the reasons for the AFE data deficiency in Eastern Europe using a taxonomic example. We selected one genus, *Rosa* L. (Rosaceae), due to its medium size (and, therefore, a significant but manageable number of species involved), some taxonomic complications involved (in certain groups but not in the whole genus), and moderately recent (not too old but still not very recent) period of mapping for AFE (Kurtto et al. 2004). In this study we focused exclusively on the background data, which is the documentation for any mapping work, because the data behind published outline distribution areas (Meusel et al. 1965, Sokolov et al. 1980, Hultén and Fries 1986), although deemed complete and accurate at the time of publication, may also be outdated and biased by assumptions, extrapolations and inaccuracies of the old paperwork style (e.g. a case study by Kazakova et al. 2019).

The genus *Rosa* is distributed in temperate and subtropical regions of the Northern Hemisphere and includes an uncertain number of species worldwide, with estimations ranging from 190 (Koopman et al. 2008) to 500 species (Buzunova 2001). The taxonomic classification and species delimitation in *Rosa* are complicated due to extensive hybridisation resulting in several hybridogenous species and many recent interspecific hybrids, which may be partly fertile and therefore capable of further hybridisation and backcrossing, and also due to infraspecific variability in some species (Ritz et al. 2005, De Cock et al. 2008, Fougère-Danezan et al. 2015, Herklotz and Ritz 2017). In dogroses (*R.* sect. *Caninae* (DC.) Ser.), the limits of species and species groups are blurred by the hybridisation which is aided by an unique type of meiosis, to the extent that no morphologically recognisable entities or genetically separated lineages can be traced (Herklotz et al. 2017).

Flora Europaea (Klášterský 1968) accepted 47 species of *Rosa* with some subspecies in Europe; no sectional classification was used but some closely related species were grouped into aggregates following the suggestion of Valentine and Heywood (1961) and Heywood (1962). Following the same approach and balancing between splitting and lumping, AFE (Kurtto et al. 2004) recognised 57 species and species groups (same as aggregates, or species *sensu lato*). These distributional data were the starting point and subject of the present study.

The mapping of *Rosa* in AFE was a special matter also because of taxonomic difficulties that obscured geographical distributions of many of the species involved (Klášterský 1968). Species concepts and taxonomic approaches varied much over times and countries, and it was only recently that the different values of species, intermediates, primary hybrids, local variants and other deviating forms were more properly understood (Kurtto et al. 2004). Besides the taxonomic challenges, the distributional data were still poorly available from Eastern Europe: on the cumulative map of all the species of *Rosa* (map 3285 in Kurtto et al. 2004), about a third of the grid cells lacked any record of the genus, and the others counted mostly 1–2 (occasionally 3–4) records per grid cell. Whereas many northern grid cells may naturally lack any *Rosa* due to climatic reasons, the low level of taxonomic diversity recorded in central and southern parts of Eastern Europe hints that undercollection may be a reason for this trend.

The aims of the present study were as follows: 1) verification of species distributions of *Rosa* in Eastern Europe and Poland, according to the grid mapping scheme of AFE; 2) collection of new occurrences of these species, complementing the distribution areas published in AFE; 3) assessing the magnitude and spatial distribution of the imperfections in the AFE data collection process, and the reasons for these imperfections.

Material and methods

Study area

We limited the scope of this study to Eastern Europe (the former USSR) and Poland due to the data availability. According to the history of studies, the countries of this territory can be classified as follows: with old traditions of botanical mapping and a long period of wide data availability (Poland), with old traditions of botanical mapping and a shorter period of wide data availability (Baltic countries), with young traditions of botanical mapping and a short period of wide data availability (Belarus, Ukraine, Moldova, Russia). Because of the current lack of active collaboration, no new data were available from Moldova, which was therefore omitted from comparisons. Some data became available from Slovakia and were included in the new records and statistics but not in the analysis.

Species distributions are indicated according to the AFE territories as in Kurtto et al. (2004), except for Uk(U) renamed to Uk and Uk(K) changed to Cm as in the forthcoming volume. The limits of these territories remain unchanged.

Taxonomy

The taxonomic scheme of AFE (Kurtto et al. 2004) was used as a backbone. This system takes into account the possibilities of splitting and lumping by accepting both narrowly delimited species and broadly defined species or species groups; it also allowed practical identifications to the level of groups only when more precise knowledge was not available. Minor corrections were implemented to this scheme in respect of species delimitations, species groups and nomenclature; these corrections were taken into account in the statistics.

Data collection

The standard practice of AFE data collection is based on herbarium specimens. In AFE, data collection and documentation has been the primary responsibility of regional collaborators (data providers); the background documentation has not been requested and not stored by the Secretariat, except for critical cases when a taxonomic or nomenclatural revision appeared necessary (Suominen 1973). The data is collected as presence or absence of a mapped taxon in a grid cell, together with status of the occurrence (native or naturalised alien, extant or extinct, certain or doubtful).

In agreement with this policy, we here collected and listed new occurrence data on the presence of native or naturalised alien taxa; in some cases it was not possible to distinguish between native and naturalised occurrences, and the status of such records was set as uncertain. In each case, the background data were subjected to rigorous taxonomic scrutiny, in which the best regional experts were involved.

We aimed at collecting a comprehensive data set from all the territories of Eastern Europe. To achieve this task, several major and minor herbarium collections were examined and screened for new records in *Rosa*, as follows (herbarium acronyms according to the *Index Herbariorum*; unregistered collections with informal acronyms are denoted by asterisks). Data providers are listed after each collection.

BILAS – Inst. of Botany of the Nature Research Centre (Vilnius, Lithuania); Z. Gudžinskas

CSAU – Academy of Agrotechnology, Crimean Federal Univ. (Simferopol, Russia); A. V. Yena

GMU – Mordovia State Univ. (Saransk, Russia); A. A. Khapugin

HMNR – Mordovia State Nature Reserve (Pushta, Russia); A. A. Khapugin

KAND – Kandalaksha State Nature Reserve (Kandalaksha, Russia); M. N. Kozhin

KPABG – Polar-Alpine Botanical Garden-Inst. (Apatity, Russia); M. N. Kozhin

KW – Kholodny Inst. of Botany (Kiev, Ukraine); N. M. Fedoronchuk

LE – Komarov Botanical Inst. (Saint-Petersburg, Russia); I. O. Buzunova

MOSP – Moscow State Pedagogical Univ. (Moscow, Russia); A. A. Khapugin

MSK – Inst. of Experimental Botany (Minsk, Belarus); D. V. Dubovik

MW – Moscow State Univ. (Moscow, Russia); A. A. Khapugin

NNSU – Nizhni Novgorod State Univ. (Nizhni Novgorod, Russia); A. A. Khapugin

*OPN – Ojców National Park (Ojców, Poland); A. Sołtys-Lelek

PKM – Penza State Univ. (Penza, Russia); A. A. Khapugin

PTZ – Karelian Research Centre (Petrozavodsk, Russia); A. V. Kravchenko

PVB – Inst. of Ecology of the Volga Basin (Togliatti, Russia); V. M. Vasjukov

SYKO – Inst. of Biology (Syktyvkar, Russia); L. V. Teteryuk

TAA – Estonian Univ. of Life Sciences (Tartu, Estonia); T. Kukk

TALL – Tallinn Botanical Garden (Tallinn, Estonia); T. Kukk

TAM – Estonian Museum of Natural History (Tallinn, Estonia); T. Kukk

UDU – Udmurt State Univ. (Izhevsk, Russia); O. G. Baranova

UFA – Ufa Research Centre (Ufa, Russia); A. A. Muldashev

UPSU – Ulyanovsk State Pedagogical Univ. (Ulyanovsk, Russia); V. M. Vasjukov

*USPE – Univ. School of Physical Education (Gorzów Wielkopolski, Poland); A. Sołtys-Lelek

VOR – Voronezh State Univ. (Voronezh, Russia); V. A. Agafonov, E. S. Kazmina

In agreement with the traditional data collection, the work focused on herbarium specimens; besides, trusted personal observations were also taken into account. Published herbarium records or observations are accompanied by references to the publications; other records have been formally unpublished and are referenced to the herbarium collections.

To analyse the sources of new information, we recorded collection dates for each occurrence; this information was used to classify the data as originated before or after the publication of Kurtto et al. (2004). Besides, we classified the herbarium institutions and individual data providers as participating or not participating in the data collection for Kurtto et al. (2004).

Since this work focused on issues in data completeness and availability, we have not examined the quality of the previously collected data as a whole. However, some parts of Rus(N) (namely, Murmansk Region) were specifically examined for the whole set of records originated from the territory. Besides covering the gaps in the previously published maps, the purpose of this examination was to check the quality of the previous data collection. This territory was selected because of the highest, nearly complete level of the current data availability, which allows for a complete coverage of modern and historical records.

The collected information was structured and processed for statistics in spreadsheets. Maps of selected species were generated using the same style as Kurtto et al. (2004) but with different colours for new records.

From the data collection we excluded the information (human observations) that has become available recently through the Global Biodiversity Information Facility (GBIF; <www.gbif.org/>). The information provided by GBIF is based on sources and principles of data collection that widely differ from those accepted by AFE (Kurtto et al. 2004), and taking these new data into account would have changed the scope and design of this study. Besides, the data quality on iNaturalist (Seregin et al. 2020) cannot be taken for granted because of many errors in identification of critical taxa (including *Rosa*: Khapugin, pers. obs.), which cannot be resolved in a short time.

Results

Taxonomy

To update the taxonomic scheme accepted in AFE (Kurtto et al. 2004), we used a variety of recent publications on the phylogeny (Bruneau et al. 2007, De Cock et al. 2008, Koopman et al. 2008, Fougère-Danezan et al. 2015), taxonomy (Zieliński 1985), morphological variability (Schanzer and Klinkova 2000, Schanzer and Vojlokova 2008), hybridisation (Schanzer and Vagina 2007, Fedorova et al. 2010), karyology (Małecka and Popek 1982, Popek 1996), nomenclature (Jarvis 1992) and regional checklists (Buzunova 2001, Buzunova and Kamelin 2004, Popek 2007, Kerényi-Nagy 2012).

We accepted 44 species, which are partly grouped into 11 aggregates at two levels of inclusiveness (Table 1). This classification is close to Kurtto et al. (2004) and also takes into account both narrower and broader taxonomic concepts. The species groups and deviations from the latter work are explained below.

Rosa cinnamomea agg. corresponds to the *R. majalis* group in Kurtto et al. (2004). The name *R. cinnamomea* was restored for *R. majalis*, following its typification by G.D. Rowley in Jarvis (1992). This species name provides the conserved type of the genus (Wiersema et al. 2015).

Rosa gallica agg. includes *R. gallica* and *R. pygmaea*, which was formerly included in *R. gallica* (Juzepczuk 1941, Klášterský 1968, Popek 1996) but restored by Buzunova (2001) and therefore accepted in Kurtto et al. (2004). The separation of the latter species was confirmed by Fedorova (2014) on the basis of morphology and genetics.

Rosa canina agg. s. lato is the same as the *R. canina* group in Kurtto et al. (2004). We found it convenient to subdivide this complex into two smaller groups (*R. canina* agg. s. str. and *R. dumalis* agg.) and two species (*R. balsamica* and *R. abietina*) which are not included in these groups.

Table 1. Species and aggregates of *Rosa* in Europe. Species order follows Kurtto et al. (2004).

№	Species	Aggregates s. str.	Aggregates s. lato
1	*Rosa sempervirens* L.		
2	*Rosa arvensis* L.		
3	*Rosa phoenicea* Boiss.		
4	*Rosa moschata* Herrm.		
5	*Rosa spinosissima* L. (*R. pimpinellifolia* L.)		
6	*Rosa acicularis* Lindl.		
7	*Rosa cinnamomea* L. (*R. majalis* Herrm.)		*Rosa cinnamomea* agg.
8	*Rosa glabrifolia* C.A. Mey. ex Rupr.		
9	*Rosa gorenkensis* Besser		
10	*Rosa donetzica* Dubovik		
11	*Rosa glauca* Pourr.		
12	*Rosa rugosa* Thunb.		
13	*Rosa pendulina* L.		
14	*Rosa gallica* L.		*Rosa gallica* agg.
15	*Rosa pygmaea* M. Bieb.		
16	*Rosa marginata* Wallr.		
17	*Rosa montana* Chaix (incl. *R. chavinii* Rapin ex Reut.)		
18	*Rosa canina* L. s. lato	*Rosa canina* agg. s. str.	*Rosa canina* agg. s. lato
19	*Rosa corymbifera* Borkh. s. lato		
20	*Rosa stylosa* Desv.		
21	*Rosa pouzinii* Tratt.		
22	*Rosa dumalis* Bechst.	*Rosa dumalis* agg.	
23	*Rosa subcanina* (Christ) Dalla Torre & Sarnth.		
24	*Rosa caesia* Sm. s. lato (incl. *R. caesia* Sm. s. str., *R. rhaetica* Gremli, *R. uriensis* Lagger & Puget ex Cottet)		
25	*Rosa subcollina* (Christ) Vuk.		
26	*Rosa balsamica* Besser		
27	*Rosa abietina* Gren. & Christ		
28	*Rosa pseudoscabriuscula* (R. Keller) Henker & G. Schulze	*Rosa sherardii* agg.	*Rosa villosa* agg. s. lato
29	*Rosa sherardii* Davis		
30	*Rosa subpomifera* Chrshan.		
31	*Rosa tomentosa* Sm.		
32	*Rosa mollis* Sm.	*Rosa villosa* agg. s. str.	
33	*Rosa villosa* L.		
34	*Rosa heckeliana* Tratt.		
35	*Rosa micrantha* Borrer ex Sm.	*Rosa rubiginosa* agg. s. str.	*Rosa rubiginosa* agg. s. lato
36	*Rosa rubiginosa* L.		
37	*Rosa agrestis* Savi	*Rosa inodora* agg.	
38	*Rosa caryophyllacea* Besser		
39	*Rosa inodora* Fr. s. lato		
40	*Rosa pulverulenta* M. Bieb.		
41	*Rosa iberica* Stev.		
42	*Rosa serafinii* Viv.		
43	*Rosa turcica* Rouy		
44	*Rosa zalana* Wiesb.		

Rosa canina agg. s. str. is the *R. canina* group s. str. in Kurtto et al. (2004) with the inclusion of *R. stylosa* and *R. pouzinii*. The proximity of *R. stylosa* to *R. canina* has been confirmed by phylogenetic studies (De Cock et al. 2008, Koopman et al. 2008). *Rosa pouzinii* is so closely related to *R. canina* that it has frequently been included in the latter species as a subspecies or variety (Crépin 1890, Keller 1931, Maire 1980, De Cock 2008). Our change of the limits of this species group does not affect its distribution in Eastern Europe.

Rosa dumalis agg. is the *R. dumalis* group in Kurtto et al. (2004), which is expanded with the inclusion of two Mediterranean species (*R. rhaetica* and *R. uriensis*), not affecting its circumscription in Eastern Europe. These two species are very close to *R. caesia* s. str. (Klášterský 1968, Kurtto et al. 2004).

Rosa villosa agg. s. lato corresponds to the *R. villosa* group (Kurtto et al. 2004). It includes the subordinated aggregates *R. villosa* agg. s. str. and *R. sherardii* agg. with two species unassigned to aggregates, *R. tomentosa* and *R. heckeliana*.

Rosa villosa agg. s. str. fully corresponds to the *R. villosa* group s. str. in Kurtto et al. (2004). Instead of the *R. tomentosa* group, we formed a more natural aggregate, *R. sherardii* agg., with the inclusion of *R. pseudoscabriuscula*, *R. subpomifera* and *R. sherardii*, that agrees with their morphology

and genetic proximity (Buzunova 2001, De Cock 2008, Koopman et al. 2008, Kerényi-Nagy and Nagy 2013). *Rosa tomentosa* is excluded from this group because of its different fruit structure (Buzunova 2001, De Cock 2008).

The circumscription of *Rosa rubiginosa* agg. s. lato is identical with the *R. rubiginosa* group s. lato in Kurtto et al. (2004). Since this group is rather heterogeneous, we decided to subdivide it into two more natural segregates.

Rosa rubiginosa agg. s. str. includes two closely related species, *R. rubiginosa* and *R. micrantha* (De Cock 2008, Koopman et al. 2008). *Rosa pocsii* Kerényi-Nagy, which is a minor segregate recently separated from *R. micrantha* (Kerényi-Nagy 2012, Kerényi-Nagy et al. 2014), is not accepted here.

Rosa inodora agg. is separated on the basis of its distinctive morphology and genetic studies (Boulenger 1924, Buzunova 2001, De Cock 2008, Koopman et al. 2008) to include *R. inodora* s. lato, *R. agrestis* and *R. caryophyllacea*.

New records

On the basis of herbarium collections, personal observations and literature data we compiled a list of records new to the *Atlas Florae Europaeae* (as published in Kurtto et al. 2004).

The list is organised alphabetically according to the accepted species names and following by the aggregate names (Table 1). The records are listed alphabetically as AFE grid cell names; sources of information (references to publications, personal communications or herbarium institutions) are specified after the grid names. The status of occurrence records is in agreement with Kurtto et al. (2004) and indicated as follows: 38UNF2 – native (including archaeophyte); *38UNF2 – status unknown or uncertain; [38UNF2] – introduction (established alien); †38UNF2 – extinct native or archaeophyte. The AFE grid system is explained elsewhere (<www.luomus.fi/en/new-grid-system-atlas-florae-europaeae>).

Species-level records
1. R. acicularis Lindl.
[34UEB3] (Zieliński 1987), [35VMF3] (TALL), [35VNF3] (TAM), *35WNS3 (Kaneva 2008), *36WVB1 (KPABG), 36WVV2 (mistakenly assigned to 36WWV2 in Kurtto et al. 2004), 36WVV4 (Kozhin 2014; KAND; LE), 36WWU1 (Abramova et al. 2003), [36UUE1] (MSK), 36WWT3, 36WWU4, 37WCM4 (all – PTZ), 38VPH4 (Gafurova 2009, 2014; LE), 38UNG4, 38UPG3, 38UPG4, 38UPF1, 38UPF3 (all – Gafurova 2014), 38VPR2, 39VVG1, 39VVH2, 39VVK4, 39VWH3, 39VWK4, 39VXK2, 39WVN1, 39WWM2, 39WWM4, 39WXM2, 40VCQ3 (all – SYKO), 40VEP3, 40VEQ2 (all – Lavrenko et al. 1995), 40WEU1, 40WFS2, 40WFT1, 41WLN3, 41WLP4 (all – SYKO), 39VWE1, 39VWD1, 39VWC1, 39VXE1, 39VXC3, 39VWD3, 39VWD4, 39VWC3, 39VWC4, 39VXC2, 39VXD4, 40VCH1 (all – UDU), 39UUV4 (all – PVB), 40VFH2, 40UDE3, 40UDE4, 40UED1, 40UEE3, 40UEE4, 40UFE1, 40UFE2 (all – UFA).

2. R. agrestis Savi
34UCV4 (Sołtys-Lelek et al. 2012, 2013, 2014; OPN).

3. R. balsamica Besser
35UPR1 (LE), 36TXQ3 (KW), 36TWQ2 (Seregin 2008), 37UDT4 (VOR), 37UDR3 (Reshetnikova and Mamontov 2007), *38ULF1 (GMU; Khapugin 2016).

4. R. caesia Sm.
34UFE3, 34UFG4 (all – BILAS), 34VEK4, 34VFK1 (all – TAA), 34UCB4, 34UCA3, 34UDA2 (all – Sołtys-Lelek 2011a; OPN), 34UFA3, 34UGA2 (all – Sołtys-Lelek and Barabasz-Krasny 2013; OPN), 35UMQ1 (Sołtys-Lelek 2011b; MDNR), 34VFH3, 34VFJ3, 35VLC4, 35VLD3 (all – Laiviņš et al. 2009), 35VMF1 (Kukk et al. 2020), 35UPR1 (LE), 34UFC4, 35UMV1, 35UNA2, 35UNB2, 35UNB3, 35UNB4, 35UNT4, 35UPT1, 35UPU1, 35UPV2, 36UUD3, 36UUD4, 36UUF2, 36UUF3 (all – MSK), *37UFA4 (GMU; Khapugin 2016), [38UME1] (Khapugin and Buzunova 2013), [38UNF4] (Khapugin 2014; GMU), 38UMV3 (Schanzer and Vagina 2007), *39UUV2, *39UUV3 (all – PVB).

5. R. canina L. s. lato
34VEH3, 34VFH1, 34VFH3, 34VEJ1, 34VEJ2, 34VEJ3, 34VFJ3, 35VLC1, 35VLD3, 35VLD4, 35VMC1, 35VMC4, 35VMD1, 35VMD4, 35VME2, 35VNC1, 35VNC2, 35VNC4, 35VLE4, 35VND1, 35UNB1 (all – Laiviņš et al. 2009), 34VFL3, 35VLE3 (all – TAA), [34UFD4], [35ULU3], [35UMT1], [35UNB1], [35UNB2], [35UPT2], [35UPU3], [36UUC1], [36UUC3], [36UUD4], [36UUE2] (all – MSK), 35UMS1 (KW), 35UNS2 (LE), 35UNS3 (KW), 35UPR1 (LE, KW), 35UPS1 (LE), 35UPS2 (LE, KW), 36UYU1 (KW), [37VFE2] (Borisova 2006), 38VLK3 (Demidova and Prilepsky 2010), 37UDT4, 37UET2, 37UDS3, 37UES3, 37UDS4, 37UES2, 37UFS4, 37UER1, 37UFQ1 (all – VOR), 37UEV4, 37UFV1 (all – Kazakova 2004), 37UFU1, 37UFA4, 37UFV3, 37UFU3, 38UNG1, 38ULF1, 38ULF3, 38UNF1, 38ULF4, 38UMF2, 38UMF4, 38UNF2, 38UME1, 38UME3, 38ULE2, 38ULE4, 38UME4, 38ULD1, 38UMD1 (all – GMU), 38UMV1 (PVB), 38UMV3 (Schanzer and Vagina 2007), 39UWU3 (Senator et al. 2011), [39VWC1], [39VWC3] (all – UDU).

6. R. caryophyllacea Besser
36TXQ3 (CSAU), 37UDU3, 37UET2 (all – VOR), *38UME3, *38UNE1 (all – GMU).

7. R. cinnamomea L. s. str.
33UXU1 (HUSPE), 33UXT3, 34UDC3 (all – Wrońska-Pilarek and Jagodziński 2009), 34UCB4 (Sołtys-Lelek 2011a), 34UDA3 (Sołtys-Lelek 2012), 34UDV1 (Wrońska-Pilarek and Jagodziński 2009), 34UEV3 (Oklejewicz et al. 2013), 34UFA3, 34UFA4 (all – Sołtys-Lelek and Barabasz-Krasny 2013), 35UMR2, 35UMQ1 (Sołtys-Lelek 2011b), 34UFC4, 35ULU2, 35ULU3, 35UMU1, 35UNA1,

35UNT4, 35UNU1, 35UNU4, 35UPA1, 35UPA3, 35UPT2, 35UPV3, 35VNE2 (Kukk et al. 2020), 36UUD2, 36UUD4, 36UUF2, 36UUF3, 36UUG2, 36UVD1 (all – MSK), 35UNP3 (KW), 35UPS2 (LE), 36UWC3 (KW), 36WVB4 (H), †35WPS2, 36WVA3, 36WWA1, 36WWV2, 36WXV1, 37WDQ4 (all – KPABG), 36WWV4 (observations of M.N. Kozhin), 36WWT3, 36WVV2, 36WWU4, 36WXS1, 37VDK3, 37VDL2 (all – PTZ), 37VDL3 (PTZ, LE), 37WEP3 (Kaneva 2003), 37WER2 (S), 37UCR3, 37UDV2, 37UDS3, 37UET2, 37UES1, 37UES2, 37UFV1, 37UFR2, 38ULD1 (all – VOR), 38UME4 (observations of A. Khapugin), 37UFV3, 37UFV4 (all – GMU), 38UNE2, 38UNG4, 39UUA3, 39UUV2, 39UUV3, 39UUV4, 39UUT1, 39UVV3, 39UVV4, 39UWA2, 39UWV1, 39UWA4, 39UWU3 (all – PVB), 39VVH2, 39VWH2, 39VWH3, 39VXK1, 39VXK2, 39VXL2, 39WVM4, 39WVN2, 39WWM1, 39WWM4, 39WWN2, 39WWN4, 40VCP4, 40VDP2 (all – SYKO), 40VDP3, 40VEP3, 40VEQ2, 40VEQ3, 40VEQ4, 40VFQ2 (all – Lavrenko et al. 1995), 40VER1, 40VER3, 40WFS2 (all – SYKO), 39VWE3, 39VWE4, 39VXE2, 39VWD1, 39VWD3, 39VXD1, 39VWD2, 39VWD4, 39VWC3, 39VWC4, 39VXC2, 39UXB1 (all – UDU), 39UXB4, 39UXA3, 40VCH2, 40VCH4, 40VDH2, 40VDH4, 40VEH2, 40VEH4, 40VFH2, 40UCG3, 40UDG3, 40UEG1, 40UFG1, 40UFG3, 40UCG4 (all – UFA), 40UCF3 (observations of A. Muldashev), 40UDG2, 40UDG4, 40UCF1, 40UDF2, 40UEF2, 40UFF4, 40UCE3, 40UDE3, 40UEE1, 40UEE3, 40UCE4, 40UEE4, 40UDD3, 40UED1, 40UED2, 40UED4, 40UFD2, 40UEC3, 40UFC2 (all – UFA).

8. R. corymbifera Borkh. s. lato
34UCA3, 34UDA1 (all – Sołtys-Lelek 2011a), 34VEH3, 34VFH1, 34VFH3, 34VFJ2, 34FVJ4, 35VLC1, 35VLC3, 35VLD4, 35VLE4, 35VMC1, 35VMC2, 35VMC4, 35VMD1, 35VMD3, 35VMD4, 35VNC1, 35VNC2, 35VNC3, 35VND1, 35VND2, 35UMB1, 35UMB3 (all – Laiviņš et al. 2009), 35UPS2 (LE), [34UFE3], [35UMA3], [35UMV2], [35UNB2], [35UNB4], [35UPU4], [36UUE1], [36UUE2] (all – MSK), 35UNS1 (KW), [37VFD2] (Borisova 2006), 37UCU3, 37UDS3, 37UES1, 37UES2, 37UFR2, 37TFN1, 37UGP2 (all – VOR), 37UEV4 (Kazakova 2004), [38UNG4] (Gafurova 2014), 38UNF3, 38UMF2, 38UNF2, 38ULE3, 38UME1, 38UME3, 38UNE1, 38ULE2 (all – GMU), 38ULD2 (Vasjukov 2006), 39UUV4, [39UVV2], 39UWA2 (all – PVB).

9. R. donetzica Dubovik
38UMV3 (Schanzer and Vagina 2007).

10. R. dumalis Bechst.
34UDV2, 34UFV1 (all – OPN), 35VMF1, 35VMF3 (all – TAA), 35UMR1, 35UMR2 (all – Sołtys-Lelek 2011b), 35ULU1, 35ULU4, 35UMV3, 35UNU1, 35UNU4, 36UUC1, 36UUE2, 36UUE4, 36UVE2 (all – MSK), 35UNS1, 35UNS2, 35UNS3 (all – LE), 35UPS1 (KW),

35UPS2 (KW, LE), 36UWC3 (KW), 36UWU2 (OPN), 36UVG1 (Buzunova et al. 2004), 37TDN2 (KW), [37VEC1], [37VDC4] (all – Seregin 2007), [37UDV3], [37UEA2] (all – Palkina 2011), [37UFA4] (Buzunova et al. 2012; GMU), *37UFU4 (Buzunova et al. 2012; LE), 37UDT4, 37UET2, 37UES1, 37UES2, 37UER2, 37UFR2, 37UFR3, 37UFQ1 (all – VOR), [38VLH3] (Borisova 1999), [38UPG3] (Pismarkina and Labutin 2013), *38UNG2 (GMU), *38UNF2 (Buzunova et al. 2012, Khapugin 2013; GMU, MW), *38UMF2, *38UME1, *38UME3, *38UME4 (all – GMU), 38UME2 (Ageeva et al. 2010), *38UNE1 (Pismarkina 2013; MW), 38ULC1 (Sukhorukov 2006), 38ULD2 (Vasjukov 2006; MW, LE), 38ULD4 (Sukhorukov et al. 2004), *38UMD3, 38UMD4 (all – Vasjukov et al. 2004), 39UUV2, 39UUV4, 39UVV2, *39UUU1 (all – PVB).

11. R. gallica L.
34UCV4 (Sołtys-Lelek et al. 2013), [34UFC4] (MSK), 35ULR3 (Fedorova et al. 2010), 37UDP1 (Fedorova 2014).

12. R. glabrifolia C.A. Mey. ex Rupr.
[34VEH1], [34VEH2], [34VEH3], [34VEJ2], [34VEJ3], [34VEJ4], [34VFJ2], [34VFH1], [34VFH3], [34VFK4], [35VLC1], [35VLC4], [35VLD3], [35VLD4], [35VLE4], [35VMC2], [35VMC4], [35VMD1], [35VMD2], [35VMD4], [35VNC2], [35VND1], [35VND2] (all – Laiviņš et al. 2009), [34VFL1], [35VNF1] (all – TAA), 35UMQ1 (Sołtys-Lelek 2011b), [34UFC3], [35UMA4], [35UNU1], [35UPA3], [36UUC1], [36UUD4], [36UUE1] (all – MSK), 35UMT2 (KW), 35UNS3, 35UPS1 (all – LE), [36VXJ4] (Notov et al. 2006), 37UFB3 (PVB), 37UFA3 (GMU), 37UEA2 (Palkina 2011), 37UDS3, 37UES1, 37UES4, 37UFS4, 37UER1, 37UFR2 (all – VOR), 38VMK4, 38VNK4, 38VNJ1, 38VMH1, 38VMH2, 38VMH4, 38ULG3, 38UMG3, 38UMG4, 38UMF3 (all – NNSU), 38UNG2, 38UNF1 (all – GMU, NNSU), 38UNG4 (LE), 38VPH2, 38UPG1, 38UPF3, 39UUB1 (all – Gafurova 2014), 38ULF3 (GMU, HMNR), 38ULF1, 38ULF2, 38ULE3, 38ULE4, 38UMF2, 38UME2, 38UMF4, 38UME3, 38UME4, 38UNF2 (all – GMU), 38UNE3 (GMU, UPSU), 38UPE1 (LE, GMU), 38UMD2, 38UMC1 (all – PKM), 38UPD4, 39UUU1 (all – LE), 39UUV1 (Rakov et al. 2014), 39UUV3, 39UUV4, 39UVV3, 39UVV4, 39UWV1 (all – PVB), 39VUL4, 39VVJ1, 39VWG1, 39VWH3, 39VXJ2 (all – SYKO), 39VWE4, 39VXE2, 39VWD1, 39VWD2, 39VXD1, 39VXD2, 39VWC3, 39VWC4, 39VXC1, 39VXC2, 39UXB3 (all – UDU), 39VXC4, 39UXB4, 39UXA3, 40VEH2, 40VEH4, 40VFH2, 40UCG3, 40UDG1, 40UDG3, 40UEG1, 40UEG3, 40UCG4, 40UDG4, 40UEG4, 40UFG2, 40UCF2, 40UCE3, 40UDD1, 40UDD3, 40UED1, 40UFD1, 40UFD2, 40UEC3 (all – UFA).

13. R. glauca Pourr.
33UXU1 (HUSPE), [34VEH1], [34VEJ3], [34VFH1], [34VFH3], [34VFJ1], [34VFJ2] (all – Laiviņš et al. 2009),

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[34UEG1] (BILAS), [35UNB1] [35VLC1], [35VLC2], [35VLC4], [35VLD3], [35VMD1], [35VMD4], [35VME2], [35VNC1], [35VNC2], [35VNC3], [35VND2] (all – Laiviņš et al. 2009), [34VEH2], [35UMA1] (all – BILAS), [35VLF3], 35VME2 (all – TAA), [34UFD4], [35UMV3], [35UNA2], [35UNB2], [35UPT2], [36UUE4] (all – MSK), 35UMR2, 35UMQ1 (all – Sołtys-Lelek 2011b), [36VXJ4] (Notov and Markelova 2005, Notov et al. 2006), [37VFE1], [37VFE2], [37VDC4] (all – Borisova 2006), [37VED4] (Borisova 1999), *37UET2 (VOR), [38ULD2] (GMU), [38ULD3] (PKM), [38ULD4] (Sukhorukov 2002), [38UME3] (GMU), [38UNF2] (Khapugin 2012; MW, GMU), [38UPE1] (UPSU).

14. R. gorenkensis Besser
[34UDD3], [34UED3], [34UDD4], [34UFD2], [34UFD4], [33UXT3], [34UEC3] (all – Marcinuk et al. 2011), [33UXT4], [34UDB1], [34UDB2], [34UEB1] (all – Piwowarski 2013), [34UEB3] (Marcinuk et al. 2011, Piwowarski 2013), [34UDA3] (Sołtys-Lelek 2012), 35UMQ1 (Sołtys-Lelek 2011b), [34VFH1], [34VFJ2], [34VFJ4], [35UMB1], [35VLC1], [35VLD4], [35VMD3], [35VND1] (all – Laiviņš et al. 2009), 35UPS1, 35UPS2 (all – LE), [34VEL4], [35VLF3] (all – TAA), 37UFU4 (Buzunova et al. 2012; LE), 38ULD2 (Sukhorukov 2006), 38UPG1, 38UNG4 (all – Gafurova 2014), 38UNE1 (PVB).

15. R. inodora Fr. s. lato
33UWT2 (Wrońska-Pilarek and Jagodziński 2009), 34UCD2 (Zając and Zając 2001).

16. R. marginata Wallr.
34UFD2, 34UDB2, 34UDB4 (all – Wrońska-Pilarek and Jagodziński 2009), 34UDA1, 34UDA2 (all – Sołtys-Lelek 2011a), 35ULQ1 (Fedorova et al. 2010), 36TXR2 (CSAU), 37UDT2, 37UDS1 (all – Artamonov 2000).

17. R. micrantha Borrer ex Sm.
33UVT3 (Wrońska-Pilarek and Jagodziński 2009), 34UFU2 (KW), 35UMQ1, 35UMQ2 (all – Sołtys-Lelek 2011b), 35UPR1 (KW), 37UCS3 (LE).

18. R. mollis Sm.
33UWS1 (Wrońska-Pilarek 2011), 34UCE1 (Wrońska-Pilarek and Jagodziński 2009), 34VFJ1, 35VLC1, 35VLD3, 35VLD4 (all – Laiviņš et al. 2009), 34VFL3 (TAA), 34UFG4, 35ULB2, 35ULB4 (all – BILAS), 35ULT2 (KW), 35UMA2 (MSK), 37UEV2 (Kazakova 2004).

19. R. pendulina L.
[36UWF3] (Skvortsov 2005a), [36UWF4], [37UCB4], [37UCA4] (all – Skvortsov 2005b).

20. R. pygmaea M. Bieb.
35UNQ2, 36UXV1 (all – KW).

21. R. rubiginosa L.
33UXU1 (HUSPE), 34VEH3, 35VLC4, 35VMC2, 35UMB3, 35VMD4, 35VND1, 35VND2 (all – Laiviņš et al. 2009), 35ULB2, 35UMA1 (all – BILAS), 35ULU3, 35ULU4, 35ULV4, 35UNB2, 35UNT3, 35UPT2, 35UPT3, 36UUD3 (all – MSK), 35UPR1 (LE), 35ULR2, 35ULP1, 36UWU2 (all – OPN), 35UNR3 (KW), 37UCS3, 37UDR3 (all – Reshetnikova et al. 2011), 37UDV4 (Golovina 2011), [37UEV3] (Palkina 2011), 37UET1, 37UEP4 (all – VOR), 37UFU1 (Sukhorukov et al. 2004), 38ULC2 (Sukhorukov 2010; MW, LE), *38ULE3 (Buzunova et al. 2012; LE), 38UMF2 (Pismarkina 2013; MOSP), 38UNF2 (Buzunova et al. 2012; GMU), 38UME1, *38UNE1 (all – GMU), 39UUU1, 39UUV4 (all – PVB), [39VXC1] (UDU).

22. R. rugosa Thunb.
[34UCU3] (observations of A. Sołtys-Lelek), [34UFA4], [34UGA2] (all – Sołtys-Lelek and Barabasz-Krasny 2013), [34VEH1], [34VEJ3], [34VEJ4], [34VFJ1], [35VMC1], [35VNC1], [35VNC2], [35VLD3], [35VLD4], [35VMD1], [35VMD2], [35VMD4], [35VND1], [34VEH3], [34VFH3], [34VFH4], [34UEG3], [35VLC1], [35VLC2], [35VMC4], [35ULB1] (all – field observations of Z. Gudžinskas; Laiviņš et al. 2009), [34VFL1], [34VFK1], [35VNF2] (all – TAA), [35VMF2], [35VND1] (all – Kukk et al. 2020), [34UFC4], [35ULU1], [35ULU4], [35ULV3], [35UMA4], [35UMT4], [35UMU2], [35UMV4], [35UNB2], [35UNB3], [35UNT3], [35UNU2], [35UPA3], [35UPT3], [36UUD2], [36UUD4], [36UUE1], [36UUF1], [36UUF2], [36UUG1] (all – MSK), [35ULR2] (OPN), [35UNS3], [35UPR3] (all – KW), [36VVN3], [36VVN4], [36VVP2], [36VVP3], [36VWP1], [36VWP3], [36WWT4], [37VCJ4] (all – PTZ), [36WVV4] (MW, KAND), [36WWB1] (Menshakova et al. 2009), [36WWB3], [36WWU3] (all – M.N. Kozhin, pers. obs.), [37WCP3] (H), [37UET2], [38ULB1] (all – VOR), [38ULD2] (GMU), [38ULF3] (Khapugin et al. 2012; HMNR), [38UME1] (GMU), [38UNF2], [38UNF3] (all – Levin and Silaeva 2010; GMU), [38VPH4] (Gafurova 2014), [38UPG1], [39UUB2] (all – Gafurova and Konovalenko 2010), [39UVV2] (PVB), [39VWD1], [39VWC2], [39VWC3], [39VXC1], [39VXD4] (all – UDU), [40VCH4], [40UDF1], [40UCG1] (all – observations of A. Muldashev).

23. R. sherardii Davis
33UYP1 (OPN), 34VFJ4, 35VLC1, 35VLE4 (all – Laiviņš et al. 2009), 35ULU3, 35UMA2, 35UMT1, 35UMT3, 35UMT4, 35UNA4, 35UNB2, 35UNU4, 35UPT1, 36UUC1, 36UUC3, 36UUD3 (all – MSK).

24. R. spinosissima L.
[33UVV3], [33UXU2], [34UEB] (all – Zieliński 1987), [34UFA3] (Sołtys-Lelek and Barabasz-Krasny 2013), [34UFG1], [34VEH4] (all – BILAS), [34VEK3], [34VFK1], [35VLF3], [35VLF4], [35VLE3] (all – TAA), [34VEH1], [34VEH2], [34VEH3], [34VEJ1], [34VEJ2],

[34VEJ3], [34VEJ4], [34VFJ1], [34VFJ2], [34VFJ3], [34VFJ4], [34VFH3], [34VFH4] (all – Laiviņš et al. 2009), [35ULA3], [35UMB1] (all – BILAS), [35VLC1], [35VLC2], [35VLC3], [35VMC1], [35VMC2], [35VMC3], [35VMC4], [35UMB3], [35VNC1], [35VNC2], [35VNC3], [35VLD3], [35VLD4], [35VLE4], [35VMD1], [35VMD2], [35VMD3], [35VMD4], [35VND1], [35VND2] (all – Laiviņš et al. 2009), [34VFH1], [34VFH2], [35ULA2], [35ULA4], [35UMB2] (all – BILAS), [35WNQ4] (KPABG), [35WPQ2] (mistakenly assigned to 36WVV3 in Kurtto et al. 2004) (KPABG), [34UFD4], [35UMB4], [35UMU2], [35UMU3], [35UNB3], [35UNB4], [35UNV3], [35UPA1], [35UPB3], [35UPB4], [35UPT4], [36UUD2], [36UUD4], [36UUE1], [36UUF1], [36UUG1], [36UVD1] (all – MSK), 36UXA4 (KW), [36VWK4], [36VXJ4], [37VCC1] (all – Notov and Markelova 2005), 37TCK3 (Miroshnikov 2007), [38ULE3] (Levin and Silaeva 2010; GMU), *38UPF2 (GMU), [38UPE1] (UPSU), [39UUV4] (PVB), [39VXD1] (UDU), [39UXA3], [39UXV3], [40UCF1], [40UDD1] (all – UFA), [40UCE3], [40UED4], [40UFD1], [40UFD2] (all – observations of A. Muldashev).

25. R. subcanina (Christ) Vuk.
33UXU1 (HUSPE), 34UCB4, 34UCA3, 34UDA1 (all – Sołtys-Lelek 2011a), 34UCV4 (Sołtys-Lelek et al. 2012; OPN), 33UYP1, 34UDV2 (all – OPN), 34UFA2 (Barabasz-Krasny and Sołtys-Lelek 2011), 34UFA3, 34UFA4 (all – Sołtys-Lelek and Barabasz-Krasny 2013), 35VMF4 (TAA), 35VND2 (Laiviņš et al. 2009), 34UFC4, 35ULT1, 35ULU4, 35ULV3, 35UMT4, 35UMU2, 35UMV1, 35UNA3, 35UNU4, 35UNV2, 35UPA3, 35UPT2, 35UPT4, 36UUD2, 36UUD3, 36UUE3, 36UUF1 (all – MSK), 35UNS1, 35UNR1 (all – KW), 35UPS2 (LE), 35UPR1 (KW, LE), [36VXJ4] (Notov et al. 2006), 37UDT4 (VOR), 37UEU3, 37UFT1 (Sukhorukov et al. 2004), 37UFV3, 37UFA4 (all – GMU), 37UFU3 (Buzunova et al. 2012; GMU, MW), 38ULE2 (MOSP), 38ULD2, 38UNF1, 38ULF4, 38UMF2, 38UMF4, 38UMD1, 38UME1, 38UME2, 38UME3, 38UME4, 38UND4 (all – GMU), 38ULD3 (PVB), 38UNF2 (Buzunova et al. 2012; GMU, MW), 38UMC1, 38UMV1, 38UND2, 38UPD3, 39UUU1, 39UUU2, 39UUV4, 39UUU3, 39UVA4, *39UVV2, 39UWA2, 39UWV1 (all – PVB).

26. R. subcollina (Christ) Vuk.
33UXU1 (HUSPE), 33UYP1, 34UCV4, 34UDV2 (all – OPN), 34UCB4, 34UDA1 (all – Sołtys-Lelek 2011a), 34UFA2 (Barabasz-Krasny and Sołtys-Lelek 2011), 34UFV1 (OPN), 34UFA3, 34UFA4 (all – Sołtys-Lelek and Barabasz-Krasny 2013), 35UMQ1 (Sołtys-Lelek 2011b), 34VFK3, 35VLF3, 35VMF1, 35VNF1, 35VNF2, 35VNE2, 35VMD3 (TAA).

27. R. subpomifera Chrshan.
37UCA4 (Reshetnikova and Krylov 2006), 37UEU3 (Sukhorukov 2006), 37UET2, 37UFR2 (all – VOR), 38UPD3 (PVB).

28. R. tomentosa Sm.
34UEV3 (Wrońska-Pilarek and Jagodziński 2009), 34UFB2 (Nowak 2005), 34UFC4, 34UFC3 (all – MSK), 35ULR3 (Fedorova et al. 2010), 35UPR1, 35UPR3, 36UYU1 (all – KW), 37UET3 (Grigoryevskaya et al. 2012).

29. R. turcica Rouy
36TXR2 (CSAU).

30. R. villosa L.
33UXU1 (HUSPE), 34UCA3, 34UDA1, 34UDA2 (all – Sołtys-Lelek 2011a), 34VEH2, 34VEJ2, 35VLC2, 35VMD1, 35VME2 (all – Laiviņš et al. 2009), 34UFD4, 35ULT3, 35ULU1, 35ULU2, 35ULU4, 35UMA4, 35UMU1, 35UMV1, 35UMV4, 35UNA3, 35UNB1, 35UNB2, 35UNB3, 35UNT1, 35UNT4, 35UNU3, 35UPA1, 35UPT2, 35UPU4, 36UUC1, 36UUD3, 36UUD4 (all – MSK), 35UNS2, 35UNS4, 35UPS2 (all – LE), 36UWA1, 36UWC3 (all – KW), [36VXJ1], [36VXJ2], [36VWH4] (all – Notov et al. 2006), 36UXF4 (Skvortsov 2005b), 36UXB3, 37UDT4, 37UDR3, 37UET2, 37UES1, 37UER1, 37UFS4, 38ULB1 (all – VOR), [37UEV3] (Palkina 2011), 37UFA4, *38ULE1 (all – GMU), *38ULE2, 38ULE3 (all – Buzunova et al. 2012; LE), *38ULF3 (Khapugin 2014; GMU), 38UMF2, *38UME2 (all – GMU, PVB), [38UME4] (Buzunova et al. 2012; GMU), 38UNB2 (PVB).

31. R. zalana Wiesb.
33UWU2 (Wrońska-Pilarek 2011), *35ULU1 (MSK).

Aggregate-level records
1. Rosa canina agg. s. lato
35ULT1, 35ULU4, 35UMU2, 35UMV1, 35UNA3, 35UNU4, 35UPA3, 35UPT2, 36UUC1, [36UUC3], 36UUD2, 36UUD3, 36UUE3, 36UUF2, 36UUF3 (all – MSK), 35UMS1, 36UWC3 (all – KW), 36UVG1 (Buzunova et al. 2004), [36VXJ4] (Notov et al. 2006), [37VFE2] (Borisova 2006), [37VEC1], [37VDC4] (all – Seregin 2007), 37UDV3 (Palkina 2011), 37UEV4, 37UFV1 (all – Kazakova 2004), 37UCU3, 37UDT4, 37UES3, 37UDS4, 37UES2, 37UFS4, 37UER1, 37UFR3, 37UFQ1, 37UGP2, 37TFN1 (all – VOR), 37UDR3 (Reshetnikova and Mamontov 2007), 37UFA4 (Buzunova et al. 2012; GMU), 37UFV3, 37UFU1 (all – GMU), 37UFU3 (Buzunova et al. 2012; MW, GMU), *37UFU4 (Buzunova et al. 2012; LE), 37UFT1 (Sukhorukov et al. 2004), 38VLK3 (Demidova and Prilepsky 2010), [38VLH3] (Borisova 1999), [38UPG3] (Pismarkina and Labutin 2013), [38UNG4] (Gafurova 2014), 38UND4, 38UNG1, *38UNG2, 38ULF1, 38ULF3, 38UNF1, 38UNF3, 38ULF4, 38UMF2, 38UMF4 (all – GMU), 38UNF2 (Buzunova et al. 2012, Khapugin 2013; MW, GMU), *38UME1 (Khapugin and Buzunova 2013; GMU), 38UME3 (GMU), *38UNE1 (Pismarkina 2013; MW), 38ULE2 (GMU, MOSP), 38ULE4 (GMU), 38UME2 (Ageeva et al. 2010; GMU), 38UME4, 38ULD1, 38UMD1 (all – GMU), 38UPD3 (PVB), 38ULD2 (Vasjukov 2006; LE, MW), 38ULD4 (Sukhorukov et al. 2004), 38UMD4 (Vasjukov et al. 2004), 38UND2 (PVB),

38ULC1 (Sukhorukov 2006), 38UMC1, 38UMV1 (all – PVB), 38UMV3 (Schanzer and Vagina 2007), 39UWA2, 39UVA4, *39UUV3, *39UUV2, 39UUV4, 39UUU1, 39UUU3, 39UUU2 (all – PVB), [39VWC1], [39VWC3] (all – UDU).

2. Rosa canina agg. s. str.
34VEJ1, 34VEJ2, 34VEJ3, 34VFH1, 34VFH3, 34VFJ3, 35VLC1, 35VLD3, 35VLD4, 35VLE4, 35VMC1, 35VMC4, 35VMD1, 35VMD4, 35VNC2, 35VNC3, 35VNC4, 35VND1, 35VND2, 35UNB1 (all – Laiviņš et al. 2009), 34VFL3, 35VLE3 (all – TAA), [34UFD4], [35ULU3], [35UMA3], [35UMT1], [35UMV2], [35UNB2], [35UNB4], [35UPT2], [35UPU3], [35UPU4], [36UUC1], [36UUC3], [36UUD4], [36UUE2] (all – MSK), 35UMS1, 35UNS3 (all – KW), 35UPS1 (LE), 35UPS2 (KW, LE), [37VFE2], [37VFD2] (all – Borisova 2006), 37UCU3, 37UDT4, 37UDS3, 37UES3, 37UDS4, 37UES2, 37UFS4, 37UER1, 37UFQ1, 37UGP2, 37TFN1 (all – VOR), 37UEV4, 37UFV1 (all – Kazakova 2004), 37UFA4, 37UFV3, 37UFU1, 37UFU3 (all – GMU), 38VLK3 (Demidova and Prilepsky 2010), 38UNG1 (GMU), [38UNG4] (Gafurova 2014), 38ULF1, 38ULF3, 38UNF1, 38UNF3, 38ULF4, 38UMF2, 38UMF4, 38UNF2, 38ULE3, 38UME1, 38UME3, 38UNE1, 38ULE2, 38ULE4, 38UME4, 38ULD1, 38UMD1 (all – GMU), 38ULD2 (Vasjukov 2006), 38UMV1 (PVB), 38UMV3 (Schanzer and Vagina 2007), 39UWA2, 39UUV4 (all – PVB), [39VWC1], [39VWC3] (all – UDU).

3. Rosa cinnamomea agg.
33UXU1 (HUSPE), 33UXT3 (Marcinuk et al. 2011, Wrońska-Pilarek and Jagodziński 2009), [33UXT4] (Piwowarski 2013), [34UED3], [34UDD4], [34UFD2], [34UFD4] (Marcinuk et al. 2011), 34UDC3 (Wrońska-Pilarek and Jagodziński 2009), 34UEB1 (Wrońska-Pilarek and Jagodziński 2009, Piwowarski 2013), 34UCB4 (Sołtys-Lelek 2011a), [34UDB2] (Piwowarski 2013), 34UDA3 (Sołtys-Lelek 2012), 34UDV1 (Wrońska-Pilarek and Jagodziński 2009), 34UEV3 (Oklejewicz et al. 2013), 34UFA3, 34UFA4 (all – Sołtys-Lelek and Barabasz-Krasny 2013), 35UMQ1 (Sołtys-Lelek 2011b), 34UFC4, 35ULU2, 35ULU3, 35UNA1, 35UNT4, 35UNU1, 35UNU4, 35UPA1, 35UPA3, 35UPT2, 35UPV3, 36UUD2, 36UUD4, 36UUF2, 36UUF3, 36UVD1 (all – MSK), 35UMT2, 35UNP3 (all – KW), 35UNS3, 35UPS2 (all – LE), 36UWC3 (KW), †35WPS2, 36WVA3, 36WWA1, 36WWV2, 36WXV1, 37WDQ4 (all – KPABG), 36WWT3, 36WVV2, 36WWU4, 36WXS1, 37VDK3, 37VDL2, 37VDL3 (all – PTZ), 37UDV2, 37UCR3, 37UDS3, 37UET2, 37UES1, 37UER1, 37UFV1, 37UFR2, 37UFS4, 38ULD1, 37UFV3, 37UFV4 (all – GMU), 38VMK4, 38VNK4, 38VNJ1, 38VMH2, 38VMH4, 38ULG3, 38UMG3, 38UMG4 (all – NNSU), 38VPH2, 38UPG1, 38UPF3, 39UUB1 (all – Gafurova 2014), 38UNG2 (NNSU, GMU), 38UNG4 (LE, PVB), 38UPE1 (LE, GMU), 38ULF1, 38ULE4, 38UME4 (all – GMU), 38UNE2 (PVB), 38UMD2, 38UMC1 (all

– PKM), 38UPD4 (LE), 38UMV3 (Schanzer and Vagina 2007), 39VVH2, 39VWH2, 39VWH3, 39VXK1, 39VXK2, 39VXL2, 39WVM4, 39WVN2, 39WWM1, 39WWM4, 39WWN2, 39WWN4, 40VCP4, 40VDP2 (all – SYKO), 40VDP3, 40VEP3, 40VEQ2, 40VEQ3, 40VEQ4, 40VFQ2 (all – Lavrenko et al. 1995), 40VER1, 40VER3, 40WFS2 (all – SYKO), 39VWE4, 39VXE2, 39VWD1, 39VWD3, 39VXD1, 39VWD2, 39VWD4, 39VXD2, 39VWC3, 39VWC4, 39VXC2, 39UXB3 (all – UDU), 39UUV2, 39UUT1, 39UUA3, 39UUV3, 39UUV4, 39UVV3, 39UVV4, 39UWA2, 39UWV1, 39UWA4, 39UWU3 (all – PVB), 39UXB4, 39UXA3, 40VCH4, 40VDH2, 40VDH4, 40VEH2, 40VEH4, 40VFH2, 40UCG3, 40UDG3, 40UEG1, 40UFG1, 40UFG3, 40UCG4 (all – UFA), 40UCF3 (observations of A. Muldashev), 40UDG4, 40UEG4, 40UCF1, 40UDF2, 40UEF2, 40UFF4, 40UCE3, 40UDE3, 40UEE1, 40UCE4, 40UEE4, 40UDD3, 40UED1, 40UFD1, 40UED2, 40UED4, 40UFD2, 40UEC3 (all – UFA).

4. Rosa dumalis agg.
35ULT1, 35ULU4, 35UMT4, 35UMU2, 35UMV1, 35UNA3, 35UNB3, 35UNT4, 35UNU4, 35UPA3, 35UPT2, 36UUC1, 36UUD2, 36UUD3, 36UUE3, 36UUF2, 36UUF3 (all – MSK), 35UNR1 (KW), 35UNS1 (KW, LE), 35UNS3 (LE), 35UPS2 (KW, LE), 36UVG1 (Buzunova et al. 2004), 36UWC3 (KW), 36UWU2 (OPN), [36VXJ4] (Notov et al. 2006), [37VEC1], [37VDC4] (all – Seregin 2007), [37UEA2], [37UDV3] (all – Palkina 2011), 37UFV3 (GMU), 37UEU3, 37UFT1 (all – Sukhorukov et al. 2004), *37UFA4 (GMU; Khapugin 2016), 37UFU3 (Buzunova et al. 2012; GMU, MW), *37UFU4 (Buzunova et al. 2012; LE), 37UDT4, 37UET2, 37UES1, 37UES2, 37UFR3, 37UER2, 37UFQ1 (all – VOR), [38VLH3] (Borisova 1999), [38UPG3] (Pismarkina and Labutin 2013), 38UMF4, 38UMD1, 38UND4, *38UNG2, 38UNF1, 38ULF4, 38UMF2 (all – GMU), 38UNF2 (Buzunova et al. 2012, Khapugin 2013; GMU, MW), *38UME1 (Khapugin and Buzunova 2013; GMU), *38UME3 (GMU), *38UNE1 (Pismarkina 2013; MW), 38ULE2 (MOSP), 38UME2 (Ageeva et al. 2010; GMU), 38UME4 (GMU), 38UPD3 (PVB), 38ULD2 (Vasjukov 2006; MW, LE), 38ULD4 (Sukhorukov et al. 2004), 38UMD4 (Vasjukov et al. 2004), 38ULC1 (Sukhorukov 2006), 38UMC1, 38UND2 (all – PVB), 38UMV1 (Schanzer and Vagina 2007), 39UUV2, 39UUU1, 39UUU2, *39UUV3, 39UUV4, 39UUU3, 39UVV2, 39UVA4, 39UWA2, 39UWV1 (all – PVB).

5. Rosa rubiginosa agg. s. str.
34VEH3, 35VLC4, 35VMC2, 35VMD4, 35VND1, 35VND2, 35UMB3 (all – Laiviņš et al. 2009), 35ULB2, 35UMA1 (all – BILAS), *35ULU1, 35ULU3, 35ULU4, 35UNB2, 35UNT3, 35UPT2, 35UPT3, 36UUD3 (all – MSK), 35UNR3 (KW), 36TXR2 (CSAU), 36UWU2 (OPN), [37UEV3] (Palkina 2011), 37UDV4 (Golovina

2011), 37UDU3 (VOR), 37UFU1 (Sukhorukov et al. 2004), 37UET2 (VOR), 37UCS3, 37UDR3 (Reshetnikova et al. 2011), 37UEP4 (VOR), 38ULC2 (Sukhorukov 2010; MW, LE), *38ULE3 (Buzunova et al. 2012; LE), 38UMF2 (Pismarkina 2013; MOSP), 38UME1, *38UME3 (GMU), 38UNF2 (Buzunova et al. 2012; GMU), *38UNE1 (GMU), 39UUU1 (Senator et al. 2011; PVB), 39UUV4 (PVB), [39VXC1] (UDU).

6. Rosa tomentosa agg.
34UEV3 (Wrońska-Pilarek and Jagodziński 2009), 34UFB2 (Nowak 2005), 34UFC4, 34UFC3 (all – MSK), 35ULR3 (Fedorova et al. 2010), 35UPR1, 35UPR3, 36UYU1 (all – KW), 37UET3 (Grigoryevskaya et al. 2012).

7. Rosa villosa agg. s. lato
35VMD1, 35VME2 (all – Laiviņš et al. 2009), 35ULU2, 35ULU4, 35UMA4, 35UMT1, 35UMT3, 35UMV1, 35UNA3, 35UNB2, 35UNB3, 35UNT4, 35UNU3, 35UPA1, 35UPT2, 35UPU4, 36UUC1, 36UUC3, 36UUD3, 36UUD4 (all – MSK), 35UNS4, 35UPS2 (all – LE), 36UWA1, 36UWC3 (all – KW), [36VXJ1], [36VXJ2], [36VWH4] (all – Notov et al. 2006), 36UXB3 (VOR), 37UCA4 (Reshetnikova and Krylov 2006), 37UEV2 (Kazakova 2004), [37UEV3] (Palkina 2011), 37UEU3 (Sukhorukov 2006), 37UET3 (Grigoryevskaya et al. 2012), 37UDT4, 37UDR3, 37UET2, 37UES1, 37UER1, 37UFS4, 38ULB1 (all – VOR), 37UFA4, *38ULE1 (all – GMU), *38ULE2, 38ULE3 (all – Buzunova et al. 2012; LE), *38ULF3 (Khapugin 2014; GMU), 38UMF2, *38UME2 (all – GMU, PVB), [38UME4] (Buzunova et al. 2012; GMU), 38UPD3, 38UNB2 (all – PVB).

8. Rosa villosa agg. s. str.
33UWS1 (Wrońska-Pilarek 2011), 34UCA3, 34UDA1, 34UDA2 (all – Sołtys-Lelek 2011a), 35VLC2, 35VMD1, 35VME2 (all – Laiviņš et al. 2009), 34UFG4, 35ULB2, 35ULB4 (all – BILAS), 34UFD4, 35ULT3, 35ULU1, 35ULU2, 35ULU4, 35UMA4, 35UMU1, 35UMV1, 35UMV4, 35UNA3, 35UNB1, 35UNB2, 35UNB3, 35UNT1, 35UNT4, 35UNU3, 35UPA1, 35UPT2, 35UPU4, 36UUC1, 36UUD3, 36UUD4 (all – MSK), 35ULT2 (KW), 35UNS2, 35UNS4, 35UPS2 (all – LE), 36UWA1, 36UWC3 (all – KW), [36VXJ1], [36VXJ2], [36VWH4] (all – Notov et al. 2006), 36UXB3 (VOR), [37UEV3] (Palkina 2011), 37UEV2 (Kazakova 2004), 37UDT4, 37UDR3, 37UET2, 37UES1, 37UER1, 37UFS4, 38ULB1 (all – VOR), 37UFA4, *38ULE1 (all – GMU), *38ULE2, 38ULE3 (all – Buzunova et al. 2012; LE), *38ULF3 (Khapugin 2014; GMU), 38UMF2, *38UME2 (all – GMU, PVB), [38UME4] (Buzunova et al. 2012; GMU), 38UNB2 (PVB).

Statistics

There are 31 species and 11 species aggregates of *Rosa* accepted in Eastern Europe (Table 1); we provided new occurrences

for each taxon. Altogether, we collected 1052 species-level records (Table 2) and 570 species aggregate-level records (Table 3), which are new in comparison to Kurtto et al. (2004), corresponding to an increase of 5.7% to the total number of species-level records and 4.5% to the total number of aggregate-level records. The records are tabulated for each taxon according to their status (native versus established alien, status certain versus uncertain, extant versus extinct).

We also performed separate statistics of the AFE grid occurrences of *Rosa* in Eastern Europe according to the AFE territories, with calculated percentages of the new occurrences (Table 4).

The records were classified according to the type of information sources (herbarium records or personal observations), availability (published or unpublished), date of collection or availability (prior or after publication of volume 13 of AFE) and depositing institution (participating or not participating in AFE for volume 13). Six major types of information sources were defined (Table 5).

Discussion

Classification of new records according to the taxonomy

We revealed new localities for each species of *Rosa* occurring in Eastern Europe (Table 2, 3), but new records were very unevenly added to the maps. The total relative increase in the number of species-level occurrences is 5.8%, which is a noticeable addition but can hardly be considered a dramatic change in the previously collected data.

The greatest relative increase in the number of records (25–50%) was noted for *R. glabrifolia* (47.3%) (Fig. 1), *R. gorenkensis* (44.9%) and *R. donetzica* (25.0%). They all belong to *R. cinnamomea* agg., which is poorly resolved in spite of certain morphological differences separating its taxa, and the phylogenetic isolation of these taxa has been doubted (Schanzer and Vojlokova 2008). A noticeable increase in the number of records (8–13%) was observed for *R. acicularis* (12.9%), *R. subpomifera* (11.4%), *R. glauca* (10.8%), *R. cinnamomea* (10.2%), *R. rugosa* (10.0%) and *R. villosa* (9.6%). Of these, *R. subpomifera* and *R. villosa* also belong to taxonomically complicated aggregates, whose members may be easily confused with each other, whereas *R. acicularis* (Fig. 1) and *R. cinnamomea* (Fig. 2) are the most common and widespread roses. Their distribution areas include vast territories of the Russian north and east, from which chorological data has been sparsely and unevenly recorded. *Rosa glauca* (Fig. 4) and *R. rugosa* (Fig. 5) are commonly cultivated ornamental species which are frequently found in and around inhabited areas.

The greatest absolute increase in the number of records (100–150) was noted for *R. cinnamomea* (146) and *R. glabrifolia* (125), members of the widespread *R. cinnamomea* agg. Numerous records (55–90) were added on the maps of *R. rugosa* (84), *R. subcanina* (66), *R. canina* s.lato (78), *R.*

Table 2. Number of the AFE grid occurrences of *Rosa* in Eastern Europe revealed after Kurtto et al. (2004) at the level of species (according to their status). Status codes: 1. Record(s) uncertain as regards identification and/or locality; 2. Extinct. 3. Probably extinct; 4. Introduced (established alien); 5. Status unknown or uncertain; 6. Native occurrence (incl. archaeophytes).

Species	Number of occurrences in Kurtto et al. (2004)							Number of occurrences new to Kurtto et al. (2004)							Current number of occurrences							Percentage of new occurrences
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	Total
Rosa acicularis	0	1	0	20	0	365	386	0	0	0	4	2	51	57	0	1	0	24	2	416	443	12.9
Rosa agrestis	3	2	35	1	1	754	796	0	0	0	0	0	1	1	3	2	35	1	1	755	797	0.1
Rosa balsamica	10	0	51	0	1	407	469	0	0	0	0	1	5	6	10	0	51	0	2	412	475	1.3
Rosa caesia	22	5	31	3	3	533	597	0	0	0	2	3	31	36	22	5	31	5	6	564	633	5.7
Rosa canina s.lato.	2	0	2	18	0	1683	1705	0	0	0	14	0	64	78	2	0	2	32	0	1747	1783	4.4
Rosa caryophyllacea	1	0	0	0	0	72	73	0	0	0	0	2	3	5	1	0	0	0	2	75	78	6.4
Rosa cinnamomea	7	1	30	29	8	1215	1290	0	1	0	0	0	145	146	7	2	30	29	8	1360	1436	10.2
Rosa corymbifera s.lato	8	1	66	9	3	1135	1222	0	0	0	11	0	45	56	8	1	66	20	3	1180	1278	4.4
Rosa donetzica	0	0	0	0	0	3	3	0	0	0	0	0	1	1	0	0	0	0	0	4	4	25.0
Rosa dumalis	7	1	21	3	1	1038	1071	0	0	0	7	10	40	57	7	1	21	10	11	1078	1128	5.1
Rosa gallica	5	5	49	50	6	532	647	0	0	0	1	0	3	4	5	5	49	51	6	535	651	0.6
Rosa glabrifolia	0	0	0	50	12	77	139	0	0	0	33	0	92	125	0	0	0	83	12	169	264	47.3
Rosa glauca	3	0	7	162	3	187	362	0	0	0	39	1	4	44	3	0	7	201	4	191	406	10.8
Rosa gorenkensis	4	0	0	3	0	31	38	0	0	0	23	0	8	31	4	0	0	26	0	39	69	44.9
Rosa inodora s.lato	5	1	37	7	2	350	402	0	0	0	0	0	2	2	5	1	37	7	2	352	404	0.5
Rosa marginata	6	2	22	1	10	245	286	0	0	0	0	0	9	9	6	2	22	1	10	254	295	3.1
Rosa micrantha	4	0	49	2	0	672	727	0	0	0	0	0	6	6	4	0	49	2	0	678	733	0.8
Rosa mollis	2	4	29	4	0	465	504	0	0	0	0	0	13	13	2	4	29	4	0	478	517	2.5
Rosa pendulina	4	1	5	1	0	432	443	0	0	0	4	0	0	4	4	1	5	5	0	432	447	0.9
Rosa pygmaea	0	0	0	0	0	61	61	0	0	0	0	0	2	2	0	0	0	0	0	63	63	3.2
Rosa rubiginosa	10	2	47	29	25	974	1087	0	0	0	2	2	35	39	10	2	47	31	27	1009	1126	3.5
Rosa rugosa	0	0	1	752	0	0	753	0	0	0	84	0	0	84	0	0	1	836	0	0	837	10.0
Rosa sherardii	8	0	26	1	0	656	691	0	0	0	0	0	16	16	8	0	26	1	0	672	707	2.3
Rosa spinosissima	4	4	18	152	6	777	961	0	0	0	84	1	2	87	4	4	18	236	7	779	1048	8.3
Rosa subcanina	26	0	22	3	2	794	847	0	0	0	1	1	64	66	26	0	22	4	3	858	913	7.2
Rosa subcollina	22	0	30	0	1	388	441	0	0	0	0	0	18	18	22	0	30	0	1	407	459	3.9
Rosa subpomifera	0	0	0	0	0	39	39	0	0	0	0	0	5	5	0	0	0	0	0	44	44	11.4
Rosa tomentosa	5	5	68	2	3	740	823	0	0	0	0	0	9	9	5	5	68	2	3	749	832	1.1
Rosa turcica	0	0	0	0	0	47	47	0	0	0	0	0	1	1	0	0	0	0	0	48	48	2.1
Rosa villosa	1	2	51	46	10	435	545	0	0	0	5	4	49	58	1	2	51	51	14	484	603	9.6
Rosa zalana	0	0	0	2	2	38	42	0	0	0	0	1	1	2	0	0	0	2	3	39	44	4.5
Total	169	37	697	1350	99	15145	17497	0	1	0	314	28	725	1068	169	38	697	1664	127	15871	18565	5.8

Table 3. Number of the AFE grid occurrences of *Rosa* in Eastern Europe revealed after Kurtto et al. (2004) at the level of aggregate (according to their status). Status codes as in Table 2.

Aggregates	Number of occurrences in Kurtto et al. (2004)							Number of occurrences new to Kurtto et al. (2004)							Total number of occurrences							Percentage of new occurrences
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	Total
Rosa aggr. *canina* s.lato	2	0	39	5	1	2143	2190	0	0	0	10	6	70	86	2	0	39	15	7	2213	2276	3.8
Rosa aggr. *canina* s.str.	2	0	39	23	0	1882	1946	0	0	0	19	0	67	86	2	0	39	43	0	1949	2032	4.2
Rosa aggr. *cinnamomea*	7	1	30	34	8	1253	1333	0	1	0	6	0	158	165	7	2	30	40	8	1411	1498	11
Rosa aggr. *dumalis*	7	0	31	4	3	1339	1384	0	0	0	7	7	62	76	7	0	31	11	10	1401	1460	5.2
Rosa aggr. *rubiginosa* s.lato	5	2	31	25	20	1509	1592	0	0	0	2	4	32	38	5	2	31	27	24	1541	1630	2.3
Rosa aggr. *tomentosa*	7	5	64	1	2	914	993	0	0	0	0	0	9	9	7	5	64	1	2	923	1002	0.9
Rosa aggr. *villosa* s.lato	4	0	50	10	7	1529	1600	0	0	0	5	4	41	50	4	0	50	15	11	1570	1650	3
Rosa aggr. *villosa* s.str.	2	3	50	20	9	849	933	0	0	0	5	4	51	60	2	3	50	25	13	900	993	6
Total	36	11	334	122	50	11418	11971	0	1	0	54	25	490	570	36	12	334	176	75	11908	12541	4.5

dumalis (57), *R. villosa* (58) and *R. spinosissima* (87). Among these, *R. rugosa* and *R. spinosissima* (Fig. 6) are widely cultivated alien species with rapidly expanding distribution areas, *R. villosa* has probably been confused with the other hairy species, whereas the other mentioned roses are members of the complex and widespread *R. canina* agg. s.l.

Among the species aggregates, the greatest increase was found in *R. cinnamomea* agg. (165 records, 11%), which matches the increase among its species.

Evaluation of new records according to the status

As recorded in Kurtto et al. (2004), the overall majority of species-level records in European *Rosa* are native (86.9%), whereas the confirmed alien occurrences totalled 7.5%. In the set of our new records, the percentage of aliens is considerably higher (29.4%) (Table 2). This level of increase seems to correspond to the secondary range expansion of certain alien species rather than to account for the former neglect for alien plants.

The greatest number of alien occurrences was found in two species, *R. rugosa* (84 records; 10.0%) and *R. spinosissima* (87 records; 8.3%). These species have been widely cultivated as ornamental shrubs for streets and yards for over a century. The active invasion of *R. rugosa* in Europe (Bruun 2005, Kelager et al. 2013) led to its recognition as a noxious weed; its new records from Murmansk Region make the northernmost extension of its distribution area. *Rosa spinosissima* also commonly escapes into the wild in surroundings of its cultivation sites (Mayland-Quellhorst et al. 2012). The third most common naturalised alien species, *R. glauca* (44 records, 10.8%), is a traditional, highly popular ornamental plant in Northern and Eastern Europe; since this species is self-fertile (Taylor 1989), its frequent feral occurrence near populated places is easily understood. Among the other species, various members of *R. canina* agg. s.lato are more frequently cultivated and therefore may run wild.

Distribution of new records according to the mapping territories

The greatest proportion of new occurrences (Table 4) was found in Latvia (La; 43.08%). This seems to stay at odds with the conclusions of Kalwij et al. (2014) that the Baltic countries are among the best sampled territories in Eastern Europe. However, the major part of this increase comes from Laiviņš et al. (2009), whose methodology and material was completely different from the previously performed studies. This research was largely based on massive field observations with dense territorial coverage, which were performed by qualified expert botanists but not documented by herbarium specimens. This method allowed for much faster data collection and resulted in much denser coverage of sampling than the traditional methods of herbarium-based data collection allow; lately, even greater results have been obtained by citizen-science networks with observations documented by digital photographs (Seregin et al. 2020) but the quality

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Table 4. Total number of the AFE grid occurrences of *Rosa* in Eastern Europe according to the AFE territories, with percentages of new occurrences.

Territory	Species			Aggregates		
	Number of new occurrences	Percentage of new occurrences	Total number of occurrences	Number of new occurrences	Percentage of new occurrences	Total number of occurrences
By	175	35.07	499	112	21.88	512
Cm	5	3.68	136	1	0.64	156
Es	35	13.46	260	2	0.74	272
La	168	43.08	390	33	9.62	343
Lt	21	5.48	383	5	0.95	528
Po	58	5.68	1021	20	1.79	1120
Rus(C)	375	34.85	1076	267	26.86	994
Rus(E)	54	26.09	207	59	24.38	242
Rus(N)	85	14.48	587	36	12.54	287
Sk	10	3.13	320	0	0	325
Uk	82	6.35	1291	36	2.25	1599
TOTAL	1068	17.31	6170	571	8.95	6378

of this data requires case-to-case evaluation and cannot be taken for granted in taxonomically difficult genera such as *Rosa* (Khapugin, pers. obs.). If we exclude the data published in Laiviņš et al. (2009) from the statistics, the increase for La would have been 2.2%, which is the lowest among the East European territories.

Otherwise the greatest increase, both in absolute and relative numbers, was found for Rus(C) (375 records; 34.85%) and By (175 records; 35.07%). The highest record for Rus(C) may be considered surprising because this territory was certainly the best sampled among the East European territories in AFE (Lahti and Lampinen 1999, Kurtto et al. 2004, Kalwij et al. 2014), and its taxonomic coverage was considered adequate (Kalwij et al. 2014). We take this figure as natural taking into account the highest level of botanical activities in Moscow and its neighbouring territories, both in respect of collecting activities and in publications (Tikhomirov et al. 1998, Gubanov et al. 2002, Seregin 2017). The second great increase from Belarus (By) can be explained by the former sparsity of records and the currently high level of activities in this country; the *Manual of vascular plants* (Parfenov 1999) and the *Flora* (Parfenov 2009, 2013, 2017) of Belarus are quite recent.

A moderate increase in the absolute number of occurrences (50–90) can be observed in Po, Rus(E), Rus(N) and Uk. The percentage of new data in Rus(E) (26.09%) and Rus(N) (14.48%) is much higher due to the formerly sparse coverage of botanical explorations in these vast and not so easily accessible territories (Uotila 2003). The relative increase from the better studied country, Poland (5.68%), is much lower due to the active mapping programmes with a long tradition and a good density of coverage (Zając and Zając 2001, Zając et al. 2019) and also reflects a high level of current activities. Although Ukraine (82 records; 6.35%) was previously found to have a rather low density of records (Kalwij et al. 2014), its relatively low level of increase in the number of records can be explained by a lesser intensity of current floristic studies.

The low number of new records coming from Cm (5; 3.68%) and Lt (21; 5.48%) is in agreement with a good floristic coverage in these relatively small territories, as noted by Kalwij et al. (2014). On the contrary, a greater increase in Es (35; 13.46%), a country with a higher level of data density and a strong plant mapping programme (Kukk and Kull 2005), can be explained by the latest update to the national atlas with an emphasis on critical native and alien species of *Rosa* (Kukk et al. 2020).

Altogether, 17.31% of species-level records were added to the AFE dataset as a result of our study. However, visual inspection of the resulting maps (Fig. 1–6) shows that the old problem of the data sparsity in Eastern Europe, which was noted e.g. by Uotila (2003) in his comparisons of the data from Finland, former Finnish Karelia and northern Russian Karelia, remains prominently noticeable and has not been overcome by our data collection effort.

Table 5. Classification of information sources of the new records.

| Type of information sources	Number and percentage (%) of new occurrences			
	Species	%	Aggregates	%
Published before Kurtto et al. (2004)	21	1.9	9	1.4
Published after Kurtto et al. (2004)	348	31.6	158	25.1
Unpubl., specimens collected before Kurtto et al. (2004) and kept at participating institutions	111	10.1	74	11.7
Unpubl., specimens collected after Kurtto et al. (2004) and kept at participating institutions	313	28.4	181	28.7
Unpubl., specimens kept at non-participating institutions	287	26.0	207	32.9
Unpubl., observations	23	2.1	1	0.2
Total	1103	100.0	630	100.0
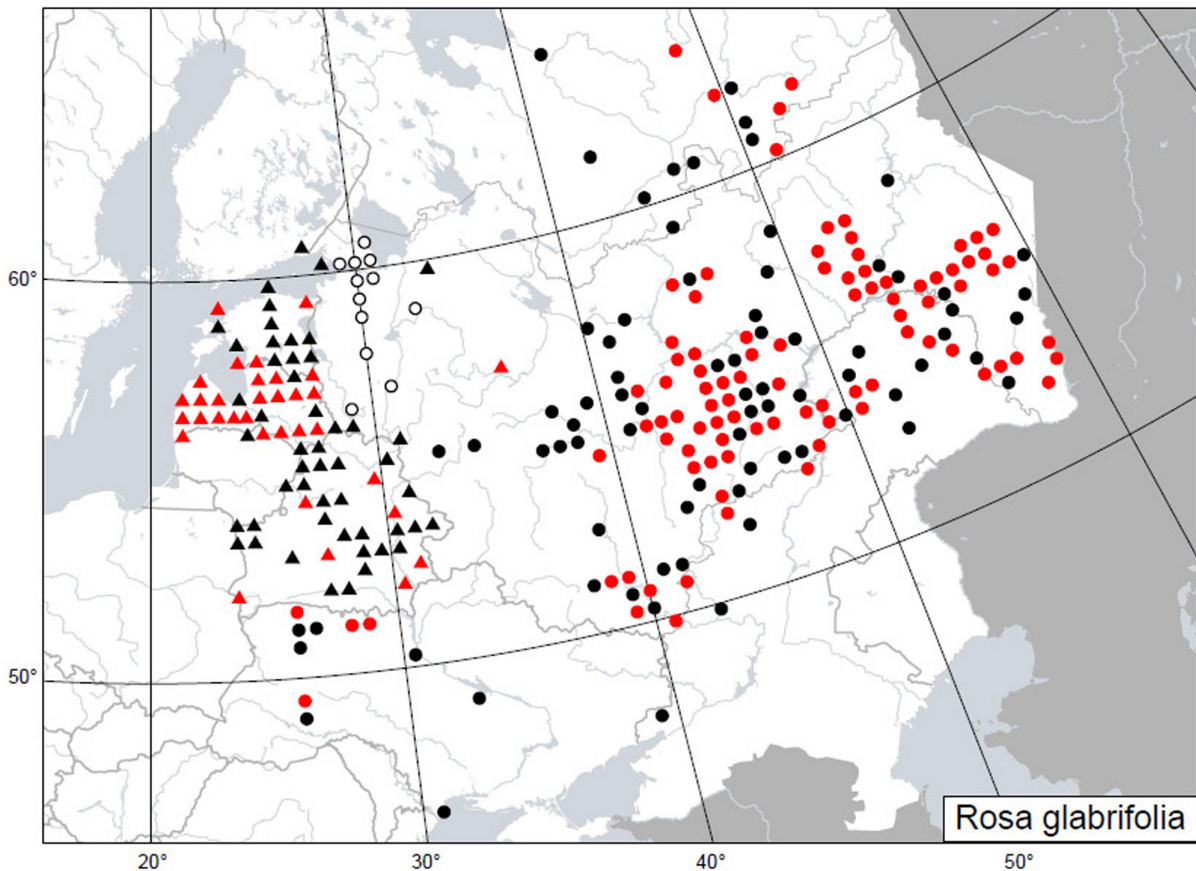
Figure 1. Updated distribution map of *Rosa glabrifolia* in Europe. Symbols: Black – published in Kurtto et al. (2004), red – added after Kurtto et al. (2004); solid circle – native occurrence; triangle – alien occurrence, circle – status unknown or uncertain; question sign – identification uncertain; oblique cross – probably extinct; cross – certainly extinct.

Data collection and availability before and after volume 13 of *Atlas Florae Europaeae*

The quality of the data collection made for Kurtto et al. (2004) was quite good. Among the new records collected for this study (Table 5), only 1.9% were published by the time of data collection and therefore overlooked by the collaborators, and 10.1% were based on herbarium specimens potentially available to the collaborators (but the actual availability may be lower because of curatorial backlogs). These possibly overlooked data account for ca 2.5% of records added to the dataset compiled by Kurtto et al. (2004), which seems to be a reasonable level of accuracy.

A quarter of our new records (28.4%) was based on herbarium specimens collected after Kurtto et al. (2004) and kept at the institutions participating in AFE. These are the major plant diversity data providers in Eastern Europe, affiliated with the largest herbarium collections, and their role in data collection remains strong.

At the same time, nearly the same number of new records based on herbarium specimens (26.0%) was obtained from institutions which were not participating in AFE. This fact highlights the need for a denser network of data providers,

ideally to cover all possible institutions. Historically, in the 1960s–1990s, the AFE data collection in Eastern Europe was centralised and very few participating institutions were involved. Volume 13, which includes *Rosa*, was the first AFE volume based on an expanded network of 'eastern' collaborators, which has been constantly growing since then. Recent efforts in making herbarium specimens available through their digital representation on the Internet, affected larger (Seregin 2020, Seregin and Stepanova 2020) and smaller (Svetasheva and Seregin 2020, Kozhin and Sennikov 2020) Herbaria in Eastern Europe and the East European holdings of non-European Herbaria (Kovtonyuk et al. 2020). Such data availability will further increase the accessibility of herbarium collections for mapping projects, and also involve collections which have probably never been considered before. The importance of smaller data providers (herbaria) in reconstruction and modelling distribution areas was also highlighted by Glon et al. (2017).

The proportion of new records received from non-collaborating institutions (287) in the total number of records (6170) is rather small (4.65%). This confirms that the early selection of major AFE data providers (in the times when electronic communication was not available or was not so
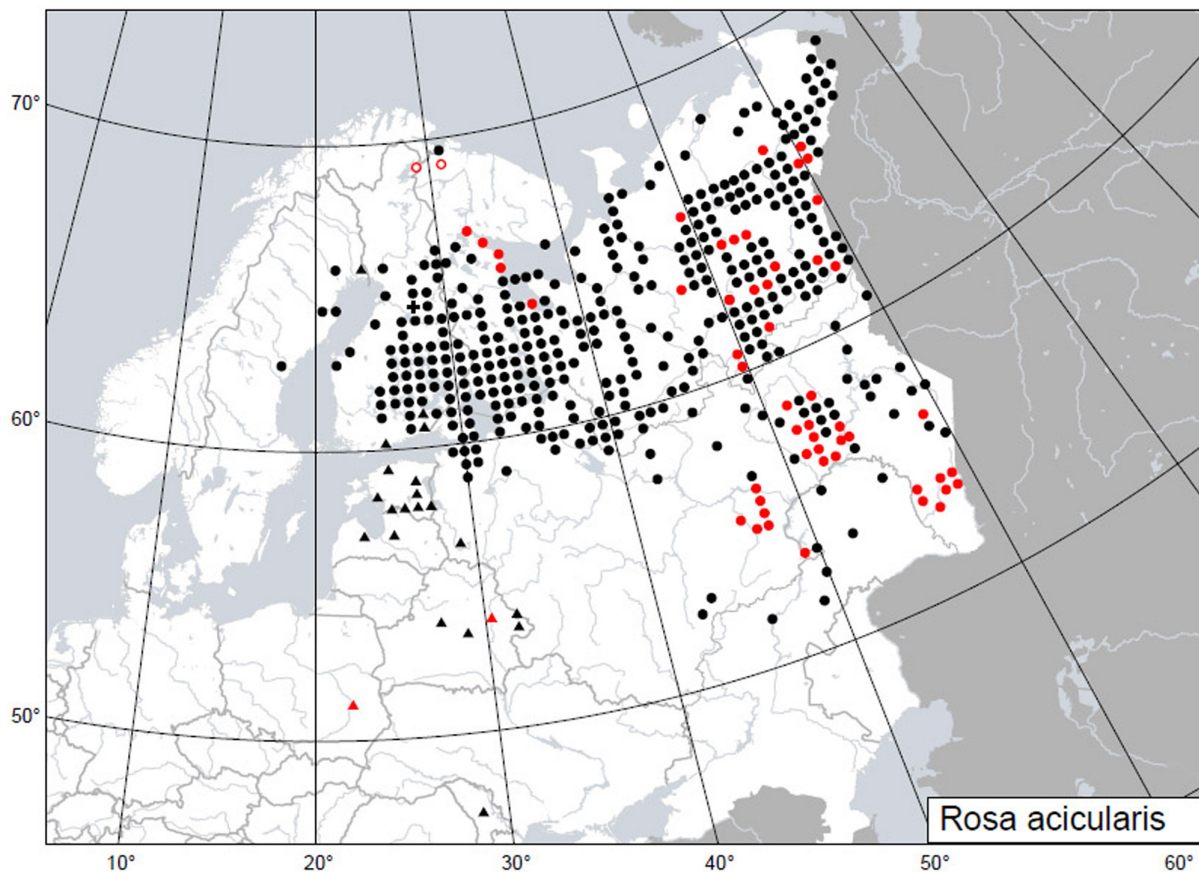
Figure 2. Updated distribution map of *Rosa acicularis* in Europe. Symbols as in Fig. 1.

well developed both between and within countries) was justified and provided the majority of records with a reasonable (albeit not always dense or complete) coverage.

The proportion of new records published after Kurtto et al. (2004) looks very high (31.6%) but includes a large set of observations published in Laiviņš et al. (2009). The proportion of published records based on herbarium specimens is much lower (19.7%) but still considerable; this figure includes numerous records based on collections kept in smaller herbaria which did not participate in AFE directly, and these data are therefore made available even without direct access to the original collections. At the same time, this figure shows that the majority of new grid records (background data) remain formally unpublished because they do not qualify for publication in traditional sets of new country-level or regional records; nowadays, such records can be published as part of curated distributional datasets (Senator et al. 2020).

The smallest addition (2.1%) was brought by undocumented observations made by data collectors. This reflects the traditional method of data collection as employed in the times of Kurtto et al. (2004), when the overall majority of records from Eastern Europe were based on herbarium specimens. Documentation by specimens has been considered especially important in taxonomically difficult groups, to allow verification or correction in subsequent studies.

Dynamics of records in a model territory

In Murmansk Region, *Rosa acicularis* is especially important because of legal protection but its coverage in Kurtto et al. (2004) and Demakhina (2014) was found not fully satisfactory. Among four records in the original data in Kurtto et al. (2004), we removed one record as lacking any background information and therefore considered erroneous, and another record was found mispositioned. The new records appearing in Demakhina (2014) were rejected as based on misidentifications. Two records added in the present work seem to be based on remnants of old cultivation and therefore should not be included in legal protection. However, altogether, the erroneous records and misinterpretations do not change the distribution area of the species.

Similarly, the only record of *Rosa spinosissima* was mispositioned in Kurtto et al. (2004) due to the misinterpretation of the original specimen label.

Our new records of *Rosa cinnamomea* from Murmansk Region are largely based on older specimens, which were available in the collections that participated in AFE (H, KPABG, S). The specimens kept at KPABG were missed because of the uncritical relying on the data completeness in *Flora of Murmansk Region* (Kozhin et al. 2020), whereas the historical specimens at H and S were neglected because they did not belong to the focus territories of those data providers.
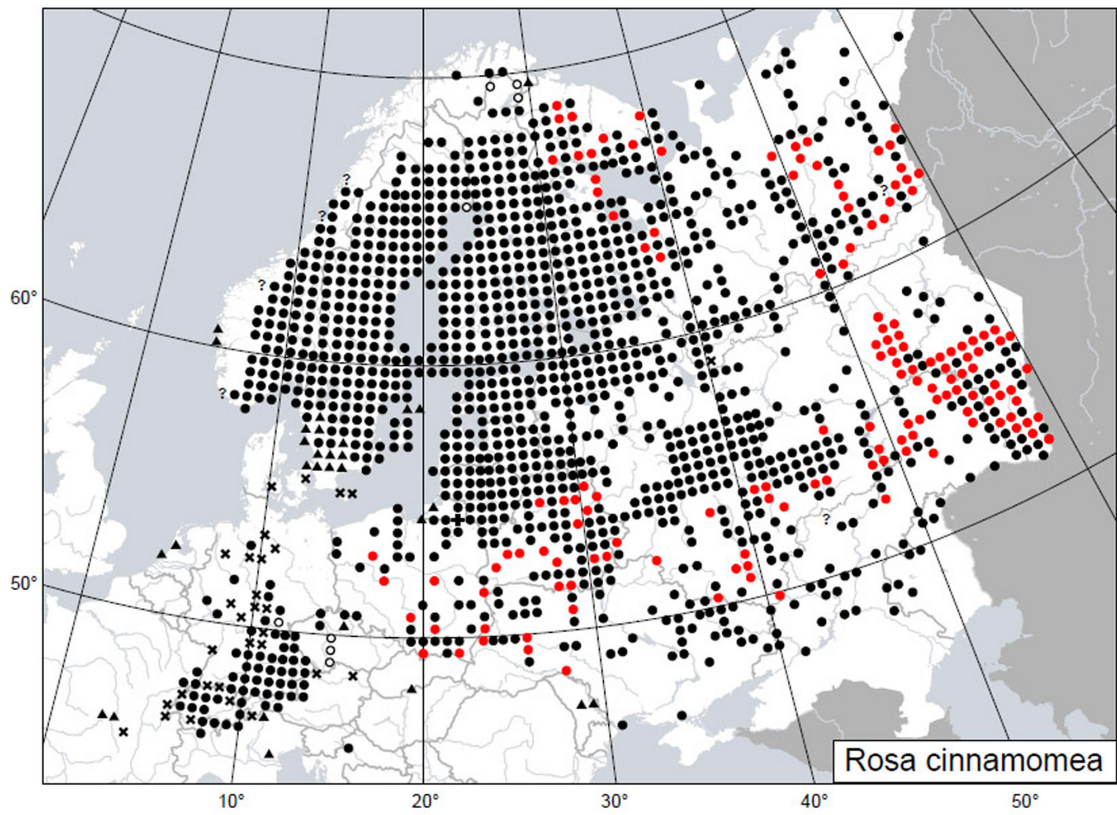
Figure 3. Updated distribution map of *Rosa cinnamomea* in Europe. Symbols as in Fig. 1.
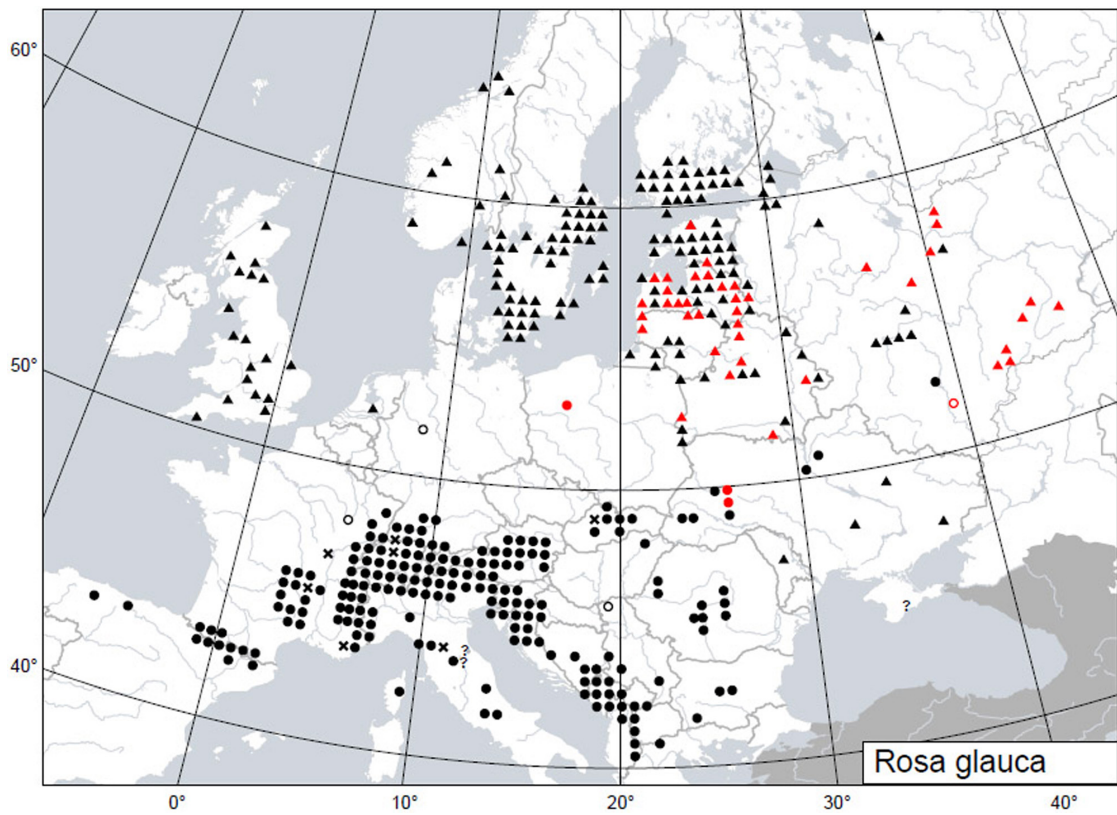

Figure 4. Updated distribution map of *Rosa glauca* in Europe. Symbols as in Fig. 1.
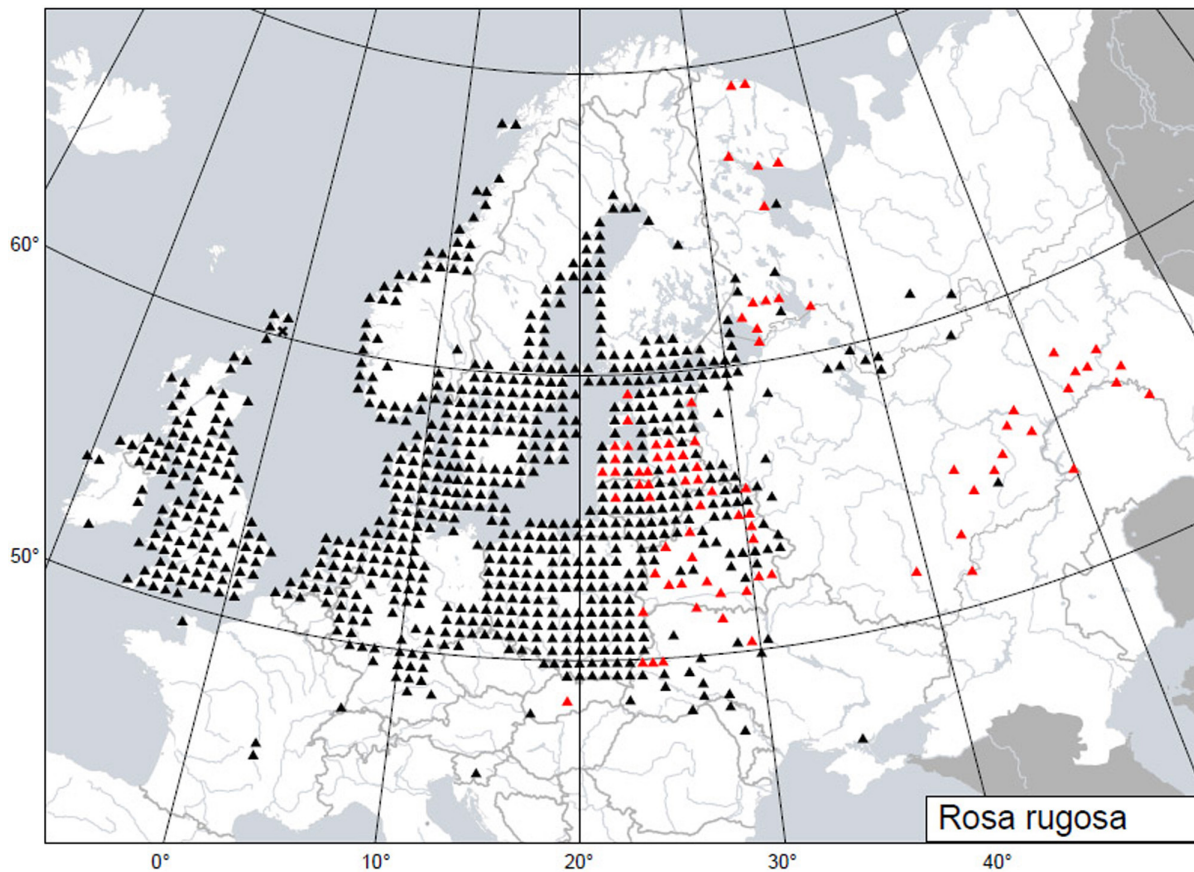
Figure 5. Updated distribution map of *Rosa rugosa* in Europe. Symbols as in Fig. 1.

Historical collections placed outside the countries of their origin may contain remarkable additions but frequently go overlooked because they may be left unused in the country of deposition and other botanists may not be aware of those collections (Sennikov 2021). This situation is analogous to the relative obscurity of smaller herbarium institutions noted above.

The ongoing expansion of *Rosa rugosa* in Murmansk Region is very recent (since 2007: Kozhin et al. 2016), and all records of this species from this territory are therefore new to Kurtto et al. (2004). Similarly to the situation in Finland (Kunttu and Kunttu 2019), this species largely spreads along the coast line and threatens native plant species and habitats by overgrowth.

Conclusions

Data re-collection in the same territory with the same methodological basis revealed about 17% of grid occurrences which were overlooked or discovered during ca 15 years after the original study. This addition is considerable but still cannot bring the distributional data from Eastern Europe to the same level of completeness and density that is available for central and northern European countries.

The original mapping quality in *Atlas Florae Europaeae* was reasonably good, with only 2.5% of the data possibly overlooked and less than 5% of the data omitted because of a smaller network of data providers. The overall sparsity of published records in Eastern Europe is therefore caused by a lower level of exploration and data collection rather than by the poor data availability.

Reassessments of old records reveal casual errors which may bear local importance but do not change the overall distribution areas.

Among the recently collected data, the amount of new herbarium records from larger and smaller data providers (herbaria) was nearly the same. Smaller herbarium collections may clearly hold many specimens which are important for tracing complete distribution areas.

The percentage of published new records based on herbarium specimens does not exceed 20%, which is caused by the selection for country-level or territorial novelties. More complete publication of new records can be effected through data papers.

The newly revealed localities reflect both a better coverage of distribution areas of native species and the recent expansion of alien plants.

The greatest number of newly revealed occurrences based on herbarium collections comes from the large territories of Eastern
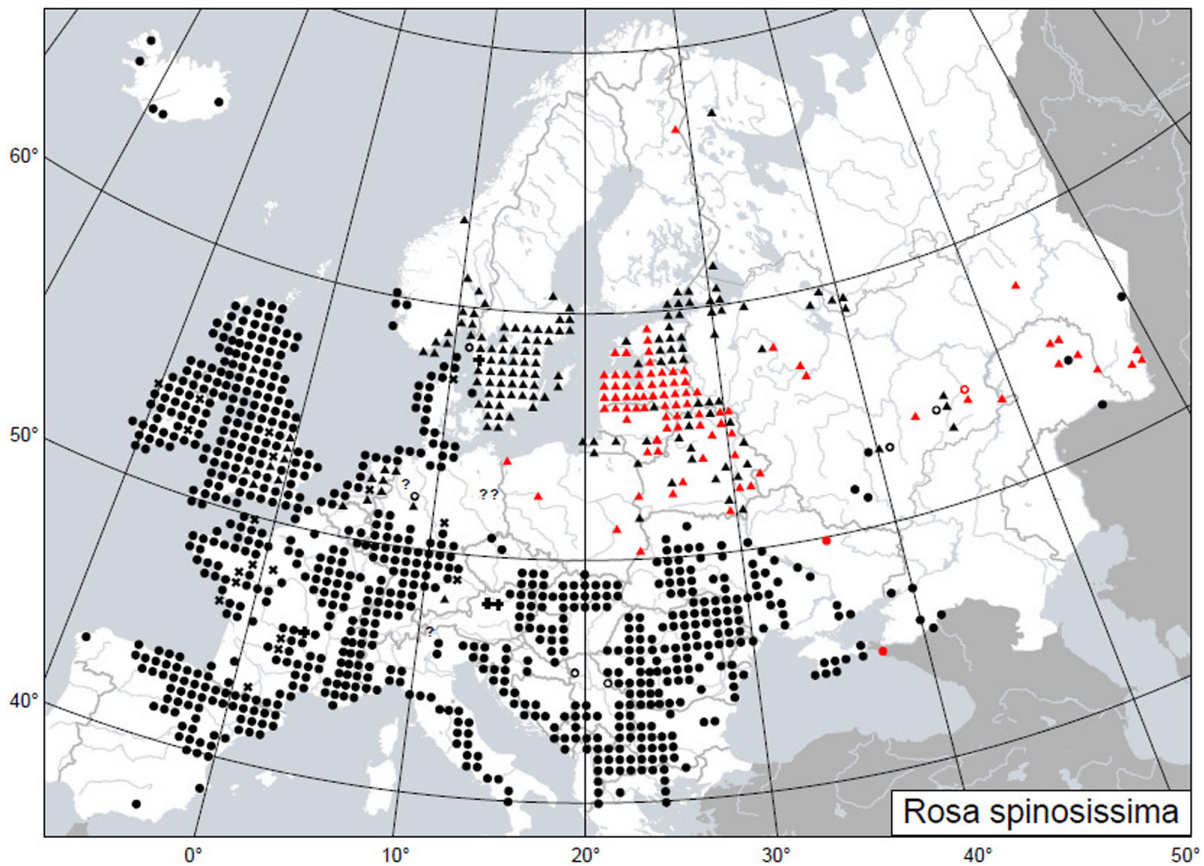
Figure 6. Updated distribution map of *Rosa spinosissima* in Europe. Symbols as in Fig. 1.

Europe which were insufficiently sampled in the past (Belarus and northern, central and eastern parts of Russia). However, many new records are coming not only from the least sampled territories in eastern and northern Russia, with extensions of distribution areas, but also from the better sampled territories, like central Russia, thus increasing the density of records.

The greatest increase in the number of records was observed for poorly studied members of taxonomically difficult groups, which received a greater attention of experts, and for the most broadly distributed species, for which both the area extension and the increasing density of records were observed. Similarly, a large increase was achieved when a territory was surveyed on purpose, with attention to taxonomically critical groups and poorly known non-native plants.

Mapping procedures based on herbarium-based data collection practices cannot compete with the accumulation of distributional data by surveys based on field lists or digital image documentation, neither in terms of speed and data coverage. However, the reliability of data collection remains dependent on the taxonomic qualification of data collectors.

Supplementary information

Other updated species distribution maps (in addition to those presented in Figures 1–6) are available as Supporting information files.

Author contributions

Anatoliy A. Khapugin: Conceptualization (equal); Data curation (lead); Formal analysis (lead); Investigation (equal); Methodology (equal); Resources (equal); Writing – original draft (lead). **Anna**

Sołtys-Lelek: Investigation (equal); Resources (equal). **Nikolai M. Fedoronchuk**: Investigation (equal); Resources (equal). **Albert A. Muldashev**: Investigation (equal); Resources (equal). **Vladimir A. Agafonov**: Investigation (equal); Resources (equal). **Elena S. Kazmina**: Investigation (equal); Resources (equal). **Vladimir M. Vasjukov**: Investigation (equal); Resources (equal). **Olga G. Baranova**: Investigation (equal); Resources (equal). **Irina O. Buzunova**: Investigation (equal); Resources (equal). **Ludmila V. Teteryuk**: Investigation (equal); Resources (equal). **Dmitry V. Dubovik**: Investigation (equal); Resources (equal). **Zigmantas Gudžinskas**: Investigation (equal); Resources (equal). **Toomas Kukk**: Investigation (equal); Resources (equal). **Alexei V. Kravchenko**: Investigation (equal); Resources (equal). **Andrei Y. Yena**: Investigation (equal); Resources (equal). **Mikhail N. Kozhin**: Investigation (equal); Resources (equal). **Alexander N. Sennikov**: Conceptualization (equal); Formal analysis (supporting); Methodology (equal); Supervision (equal); Writing – review and editing (lead).

Data availability statement

Data are available from the Dryad Digital Repository: <http://dx.doi.org/10.5061/dryad.vmcvdncsz> (Khapugin et al. 2021).

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