Viola elatior, *V. pumila* and *V. stagnina* in Austria, Czechia and Slovakia: a story of decline

***Viola elatior*, *V. pumila* a *V. stagnina* v Rakousku, České republice a na Slovensku postupně vymírají**

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Specimens of *Viola elatior* (VE), *V. pumila* (VP) and *V. stagnina* (VS) in 40 Austrian, Czech and Slovak public herbaria were revised, a total of almost 1750 specimens from the three countries. Apart from VE, the quality of the original identifications was rather poor, especially of VS, which was frequently confused with VP and *V. canina*. This, together with the confusion of nomenclature that persisted during the 19th century, made the old literature records unreliable. Hybrids are usually difficult to identify and are rarer than generally believed. VS and VP have similar distribution patterns: they occur mainly on floodplains of large lowland rivers and in adjacent hills in the N part of Bohemia, S and Central Moravia, E Austria and S Slovakia; they may be classified as river corridor plants. VS differs from VE and VP mainly by its presence in S Bohemia and its absence from large parts of S Slovakia, as well as its rarity in Austria and Slovakia. All three species grow predominantly in regions with a relatively warm and dry climate: most localities are situated in regions with a mean annual temperature of 7–11 °C and mean annual precipitation 401–700 mm. A temporal analysis of records revealed that all three species are declining in all three countries: generally, this decline is weakest in Austria, with 46–61% of grid cells with occurrences confirmed after 1980 (compared with the number of grid cells with records for 1801–2008), and strongest in Slovakia, with 18–32% of grid cells with occurrences confirmed after 1980. The decline is due mainly to the canalization of rivers and subsequent changes in land use, urbanization and recently afforestation. VE may also be endangered by modern forestry practices. The inclusion of all three species in national Red Lists and subsequent conservation measures are justified and necessary, though national Red List status may differ between countries.

K e y w o r d s: changes in frequency, conservation, herbarium, phytogeography, rare species, temporal dynamics, *Violaceae*

Introduction

Viola elatior Fries (further referred to as VE)*, V. pumila* Chaix (VP) and *V. stagnina* Kit. ex Schult. (VS, and all three as 'the violets') are members of the cosmopolitan genus *Viola* L., which includes about 400 (Valentine 1962) or 525–600 species (Ballard & Sytsma 2000). They are classified into *V.* subsect. *Rostratae* Kupffer within *V.* sect. *Viola* (Kirschner & Skalický 1990), sometimes treated at sectional rank as *V.* sect. *Trigonocarpea* Godr. and *V.* sect. *Mirabiles* (Nyman ex Borbás) Vl. V. Nikit. (Nikitin 1998), a species-rich group comprising more than 35 species and distributed in Europe, Asia and North America.

"Rostrate" violets, i.e. those with a leafy stem and a hooked style, are sometimes divided into rosulate and arosulate species. This classification is based on their growth form: rosulate species (apart from *V. mirabilis*) exhibit a long-lasting monopodial growth of the main axis, manifested by the presence of a basal leaf rosette and laterally formed flowering shoots, whereas arosulate species have a sympodially formed shoot base and lack a basal leaf rosette (Meusel & Kästner 1974). In Central Europe, the group of arosulate violets includes only VE, VP, VS and *V. canina* s.l. (Kirschner & Skalický 1990, Fischer 2005, Mereďa et al. 2008). Apart from *V. canina*, they are red-listed in Austria (Niklfeld & Schratt-Ehrendorfer 1999), Czechia (Procházka 2001) and Slovakia (Feráková et al. 2001), and classified as critically endangered, endangered or vulnerable.

Violets are notoriously difficult to identify, mainly because of their great morphological plasticity and the relatively scarce occurrence of some species, which prevents field botanists from becoming familiar with them, and to some extent also hybridization. For these reasons, literature records are often less reliable, and the knowledge of recent and past distribution is rather poor. Recently, the violets were the subject of several comparative studies of their population biology (e.g., Eckstein et al. 2004, Eckstein & Otte 2004, 2005) and reviews of their taxonomy, morphology, habitat requirements, life cycle and ecology (Eckstein et al. 2006). Unfortunately, the practical application of this knowledge is hindered by the lack or poor quality of past and present records. Thus the purpose of this paper is to present the results of a critical analysis of the past and present distribution of these species in Austria, Czechia and Slovakia, based mainly on revised herbarium specimens. It is accompanied by an attempt to study regional distribution patterns, their relationship to climatic variables, and changes in frequency and distribution in time. Some attention is also paid to hybridization and species ecology.

Methods and data

All important public herbarium collections in Austria, Czechia and Slovakia, including those of local institutions and some private herbaria, were searched for specimens of the violets. Specimens of the three species were found in the following 40 public herbaria (acronyms follow Holmgren & Holmgren 1998): BRA, BRIX, BRNL, BRNM, BRNU, CHOM, BZB, CB, ER, GJO, GM, GZU, HOMP, HR, IBF, KL, LI, LIT, MMI, MP, NBSI, NI, OL, OLM, OMJ, OP, OSM, PL, PR, PRC, ROZ, SAV, SLO, SZU, VYM, W, WHB, WU, ZM and ZMT, as well as in a few private herbaria. Plants were identified using the keys of Kirschner & Skalický (1990), Fischer (2005) and Eckstein et al. (2006). Herbarium labels were photographed or the information on the labels directly stored in a database (the database including also original label texts is available from the first author on request). Old toponyms were converted into their current official form, mainly according to topographic or hiking maps and road atlases, and geographical coordinates or grid numbers of the Mapping the Flora of Central Europe project (Niklfeld 1971) were found, using digital maps and internet sources. The list of revised specimens with abridged locality information in Electronic Appendix 1 is arranged according to federal states (in Austria) or units of the phytogeographical division of Czechia (Skalický 1988) and Slovakia (Futák 1984), and alphabetically. The field records from Austria are arranged according to the quadrants of the Central European recording grid (see below). The distribution maps were drawn with the aid of computer program DMAP (Morton 2005).

The relationship between climatic variables and species' distribution was analysed in GIS, using data from the Climate Atlas of Czechia (Tolasz et al. 2007) and the set of global climate layers WorldClim (Hijmans et al. 2008). To visualize these relationships, densities of records per 1000 km^2 were calculated for each interval of a climatic variable, which makes better ecological sense than absolute numbers of records.

In order to assess changes in frequency with time, two scales were chosen, the number of records and number of quadrants (= quarters; 3' geographical latitude × 5' geographical longitude) of basic fields or MTBs (Niklfeld 1971). Each record usually includes locality and frequently habitat, as well as the date and recorder. However, some of the old herbarium specimens could not be precisely located and often the year or even the name of the collector was not recorded. If some information was lacking, the record was used only for some analyses: for example, records lacking information about the year of collection were used for plotting distribution maps, whereas records with poorly described localities were used when analysing change in time. When assigning broadly localized records to quadrants or sites, a conservative approach was adopted: in doubtful cases records were assigned to sites or quadrants with occurrences documented by records with more precise locality information. Duplicate records were eliminated if they were recognized as such; in some cases, arbitrary decisions had to be taken.

To show the number of individual records for each species in each country over time, frequency curves were drawn in a spreadsheet. To account for fluctuations in recording, the data were smoothed using 11-year moving averages (cf. Rich & Karran 2006). The curves presented here include the period 1831–2000, with moving averages based on data from 1825–2005; some earlier records exist for all three species but they are often undated. Only the records from Czechia could be corrected for botanical activity, based on a preliminary dataset representing 17,573 specimens of 33 species in 32 Czech public herbaria (J. Danihelka et al. unpubl.; cf. Rich 2006).

Assessing changes in distribution in time using quadrants of basic fields, a quadrant with any record regardless of its date is considered as occupied at the starting point of this analysis. This assumption is based on the biological traits of these violets: they are long-lived perennials with ballistic dispersal plus dispersal by ants (diplochory; cf. Eckstein et al. 2006), so they have only a limited ability to spread and colonize new remote sites, especially in the fragmented Central-European landscape of today, in which extensive floods are scarce.

The records were classified into three groups: (1) before 1950, (2) 1950–1980 and (3) after 1980. This division is based mainly on the history of land use and farming in the former Czechoslovakia: major changes in agriculture, including the introduction of collective farming, followed by large-scale drainage and conversion of meadows into arable land, and regulations governing rivers started in the early 1950s and were mainly completed in the late 1970s or early 1980s. Further, a species not recorded for 25–30 years is considered as missing in the Czech Red List (Procházka 2001), and this time span can also be applied to individual sites or grid cells.

Most analyses are based on herbarium specimens but some field records from the project Mapping the Flora of Austria and a few from the Czech Republic (often documented by photographs) were used when plotting distribution maps. They are also given in Electronic Appendix 1.

Results and discussion

Herbarium studies

Altogether, 1746 herbarium specimens (not including hybrids and uncertain identifications) from Austria, the Czech Republic and Slovakia and about 450 specimens from other parts of the species' ranges were studied. Numbers of herbarium specimens seen per species and country are given in Table 1.

The earliest herbarium specimens of the violets were collected at the turn of the 18th century or shortly afterwards; in fact, some earlier records, usually undated, often with general locality information and without the name of the collector, are likely to have remained unrecognized. The earliest herbarium specimen of VE was probably collected near Perchtoldsdorf in Lower Austria (as *V. montana*; ex herb. Jacquin, undated). Further early specimens of this species were collected near Emmerberg, probably by J. Zahlbruckner in 1806, and by numerous collectors in Brigittenau, now a neighbourhood of Vienna, around 1825 or earlier. In Czechia, VE was first collected probably by C. B. Presl (as *V. ruppii*; undated gathering from "Bohemia") and by A. Carl in 1818 near Uherské Hradiště in southeastern Moravia. The earliest Slovakian herbarium record from Podunajské Biskupice near Bratislava by A. Pavlik goes back to 1848. However, the earliest literature record for Slovakia, "In pratis auf der Kapitelwiese [near Bratislava]", is that published by Lumnitzer (1791: 396 as *V. montana*).

The earliest dated Austrian specimen of VP was collected in Lainz near Vienna by F. von Portenschlag-Ledermayer in 1809. In Czechia, its occurrence was documented by Ch. F. Hochstetter near Lednice in southern Moravia in 1823 or somewhat earlier (identified as *V. persicifolia* and distributed as no. 127 of the Gewächse des Brünner Kreises in summer 1823) and by F. M. Opiz near Brandýs nad Labem in Bohemia in 1835, whereas the earliest Slovakian herbarium specimen was collected in 1853 by G. Lorinser from Bratislava.

The oldest herbarium specimen of VS from Austria was collected by J. Maly in Stockerau near Vienna in 1829 (as *V. lactea*; a mixed collection containing also *V. canina* and VP) and that from Czechia by F. M. Opiz near Pardubice (as *V. ruppii*; undated, but probably before 1819) and near Poděbrady in 1836 (as *V. lactea*), while in Slovakia, this species was first documented in 1864 by the specimen collected by J. Wiesbaur at an unidentified site in Bratislava ("Meeräugel"). This situation reflects both the history of botanical research and the morphology of these species, with VE being the most easy and VS the most difficult to recognize, as well as their regional frequency.

Quality of the identifications and literature records

The quality of the identifications is difficult to evaluate because (i) we did not note original identifications of some dozens of specimens in the first phase of this study and, mainly, (ii) because of the very difficult synonymy and nomenclatural confusion, concerning all three species. The nomenclatural difficulties are described by Eckstein et al. (2006). VE was originally treated under the earliest and correct Linnean name *Viola montana*, as indicated by the labels of some specimens collected in the late 18th and early 19th century. This name was later replaced by *V. persicifolia* Schreb. and eventually around 1850 by *V. elatior* Fries. In some periods, however, the illegitimate but unambiguous name *V. erecta* Gilib. was also used. The earliest collections of VS were identified as *V. lactea* Sm., but this

Table 1. – Numbers of herbarium specimens studied per species and country (including duplicates from different herbaria); numbers in parentheses indicate numbers of specimens of uncertain identification.

Species / Country	Austria	Czechia	Slovakia	Altogether
Viola elatior	177 (+ 1)	222 (+ 3)	94 (+ 3)	493 (+ 7)
Viola pumila	280 (+ 2)	315 (+ 4)	128 (+ 2)	723 (+ 8)
Viola stagnina	58 (+ 3)	368 (+ 12)	74	500 (+ 15)

name, later replaced by *V. stagnina* Kit. ex Schult., was simultaneously used also for VP. In some periods, *V. persicifolia* was accepted as correct for VS but the same name was also applied to VP. It is therefore very difficult to distinguish between misidentifications and the use of incorrect names.

Of the 493 VE specimens seen, 3 were identified as *V. pumila*, 3 as *V. pratensis* Mert. & Koch, 2 as *V. schultzii* Billot, 12 as *V. stagnina* and 5 as *V. stricta* Hornem. In contrast, 20 specimens originally identified as *V. elatior* were referable to VP, and 18 identified as *V. elatior* or *V. erecta* to VS, while misidentifications of other *Viola* species as *V. elatior* were not recorded. The success rate was much lower for VP and VS. Of the 723 VP specimens seen, 76 were identified as *V. stagnina* and a further 25 as *V. persicifolia*, which might not always have been a mistake. The misidentifications of VP as *V. stagnina* were especially frequent in Austria and Slovakia, where VS is rare. Along with the 58 specimens of VS from Austria seen, there were another 39 specimens originally identified as *V. stagnina* and 17 as *V. persicifolia*, respectively, but in fact all referable to VP. In Slovakia, VS was represented by 74 specimens, but further 12 specimens originally identified as *V. persicifolia* or *V. stagnina* were VP. The overall poor knowledge of these violets can be also documented by the very frequent mixed collections (even by renowned botanists), containing two or three species.

The literature records are also very unreliable for reasons other than the many misidentifications and confused nomenclature. Some 19th-century floras that cover regions where all three species occur contain only one species, mainly *V. persicifolia* (e.g., Rohrer & Mayer 1835). Sometimes the three species are included as infraspecific taxa of *V. persicifolia* (e.g., Neilreich 1859, Makowsky 1863, Duftschmid 1885) or even of *V. canina* (Neilreich 1846: 525–526). And even if they were treated as species, their species status was questioned, as by Čelakovský[1] (1875: 481). Another source of bias was the uncertainty about the delimitation of taxa, especially VS. Neilreich (1846: 526) included some populations of *V. canina* into his *V. canina* var. *stagnina*, whereas Neilreich (1859: 773) and Duftschmid (1885: 22) included some populations of *V. canina* into their *V. persicifolia* var. *stagnina*; this is clear both from the synonymy (including *V. ruppii* "Reichenb." and *V. nemoralis* Kütz.) and sites listed therein. With a field flora of the former Czechoslovakia (Polívka et al. 1928), which contained a better identification key (but rather poor drawings), the quality of identifications improved in the late 1920s. However, the records in the literature prior to 1900 are almost useless.

[1] „Dass die hier angeführten ‚Arten' alle echte Arten sind, glaube ich nicht, doch konnte ich sie bisher zu wenig in der Natur beobachten, um mit Bestimmtheit Art und Race sondern zu können, daher ich es vorzog, nach Koch's und Uechtritz's Vorgange auch die muthmasslichen Racen gesondert aufzuführen."

Hybridization

The identification of hybrids in herbaria was very difficult due to the considerable morphological plasticity of VP, VS and *V. canina*, another species frequently involved in hybridization. All plants of putative hybrid origin were sterile (cf. Røren et al. 1993; but see the opposite statement about hybrid swarms between *V. canina* and VP in Kirschner & Skalický 1990: 430) and more or less morphologically intermediate. The hybrid *V. canina* × *V. stagnina*, for example, observed at a site near Olomouc, had flowers similar to *V. canina* but vegetative parts resembling more those of VS (for more information about hybridization see Eckstein et al. 2006 and references therein).

Hybrid combinations recognized in herbarium records from the field include *V. canina* × *V. pumila* (= *V.* ×*semseyana* Borbás; documented from AT, CZ, SK), *V. canina* × *V. stagnina* (= *V.* ×*ritschliana* W. Becker; AT, CZ, SK?), *V. elatior* × *V. pumila* (*V.* ×*skofitziana* Wiesb.; AT, SK?) and *V. pumila* × *V. stagnina* (*V.* ×*gotlandica* W. Becker; CZ). Of these, the most common involved *V. canina* as one parent and VP or VS as the other. They were not found in alluvial habitats but mainly in lowland fen meadows of adjacent hill country in central and eastern Bohemia. There are more than 10 specimens of the hybrid VE × VP from the vicinity of Vienna in Lower Austria but no specimens from Czechia. Some records of VE × VP listed by Kirschner & Skalický (1990: 430) are from sites where the occurrence of VE is not supported by herbarium specimens, and therefore these records are rather unlikely to be correct. The only record therein of VE × VS ("Pardubice, Studánka") is based on a plant that we identified as *V. stagnina*.

The number of hybrid plants (including those identified as uncertain) is generally much smaller than that recorded by Kirschner & Skalický (1990), and some collections formerly identified as hybrids consist, in our opinion, of two species or aberrant plants. Such collections, however, including one or both putative parents and a hybrid, facilitated the recognition of the latter. But for a reliable identification of hybrids, observation of living plants in the field and in some cases also chromosome counts are necessary. Hybrid specimens, including those that are uncertain, are listed in Electronic Appendix 1.

Distribution pattern

The main strongholds of VE and VP in the three countries (Figs 1 and 2) are the river corridors of the Elbe, Dyje/Thaya River, Morava/March River, Danube and Váh River, and the Bodrog River in the very east. Both species also occasionally occur at sites not in river corridors: for instance, VE was found at Oškobrh Hill near Poděbrady in Bohemia and at three sites in the White Carpathians in southeastern Moravia, while VP is recorded from a large part of the Bohemian Cretaceous Table in central and eastern Bohemia north of the Elbe, the hill country southeast of Brno, the White Carpathians in southern Moravia, the Leitha Lowland in Lower Austria and around Neusiedl Lake in the province of Burgenland. The occurrences of VP away from river corridors were confined mainly to lowland fen meadows or slopes below springs supplying water rich in minerals. The distribution of both species corresponds to the distribution pattern described by Burkart (2001) and termed "river corridor plants" (Stromtalpflanzen), but this pattern is somewhat blurred by the localities for VP away from river corridors. Also the distribution pattern of both species in Poland (Zając & Zając 2002) is very similar in this respect. This is probably because all four countries are situated in the transition zone between the typical river corridor

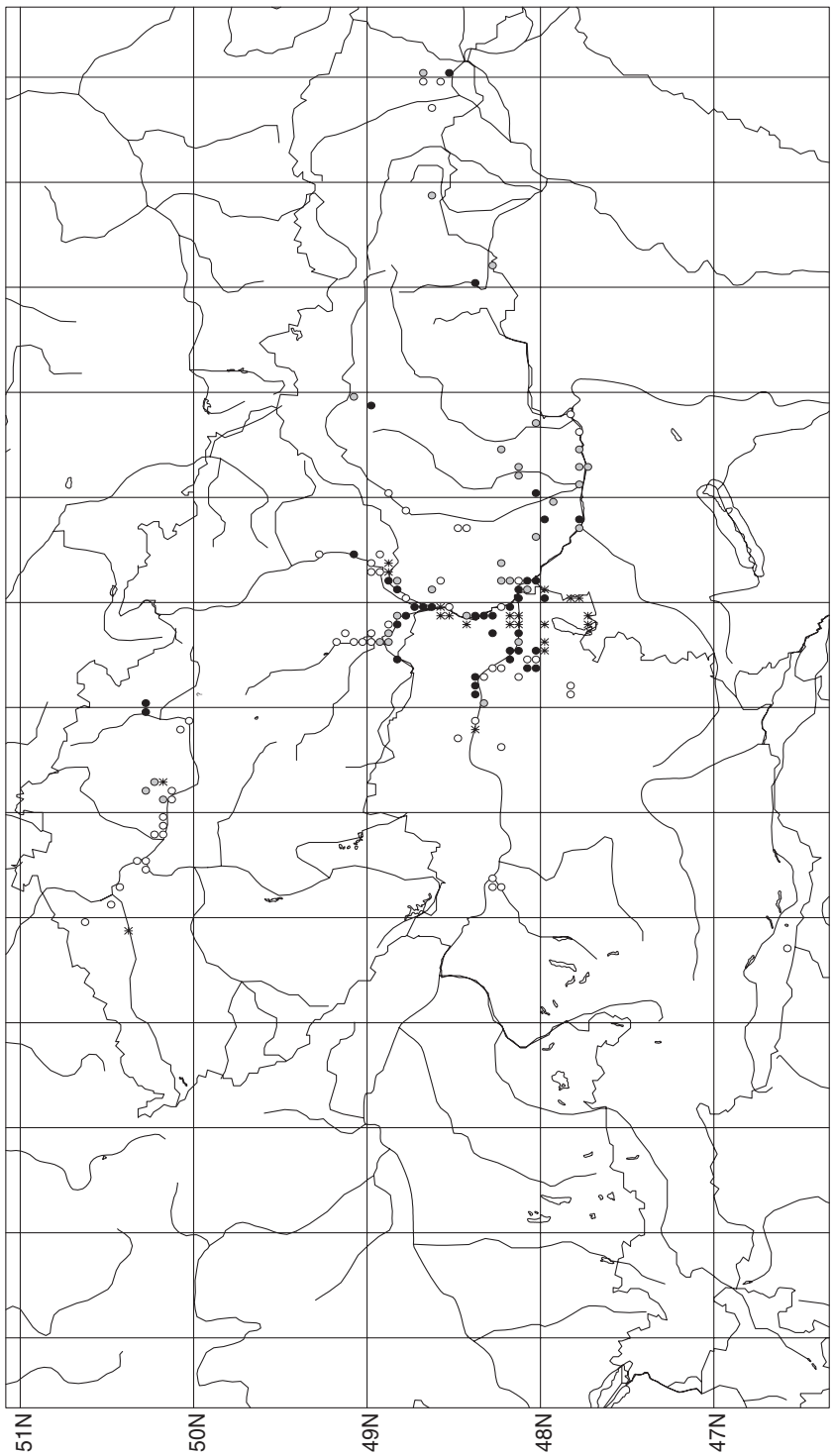

Fig. 1. – Distribution of *Viola elatior* in Austria, Czechia and Slovakia. Recording unit is a quarter of the basic field of the Central European Mapping Scheme. Symbols: empty circles – herbarium specimens before 1950; grey circles – herbarium specimens from 1950–1980; black circles – herbarium specimens after 1980; asterisks – field records after 1980. In Austria occurrences documented by herbarium specimens before 1950 or in 1950–1980 and later confirmed in the field are plotted as herbarium specimens from 1950–1980 or after 1980, respectively.

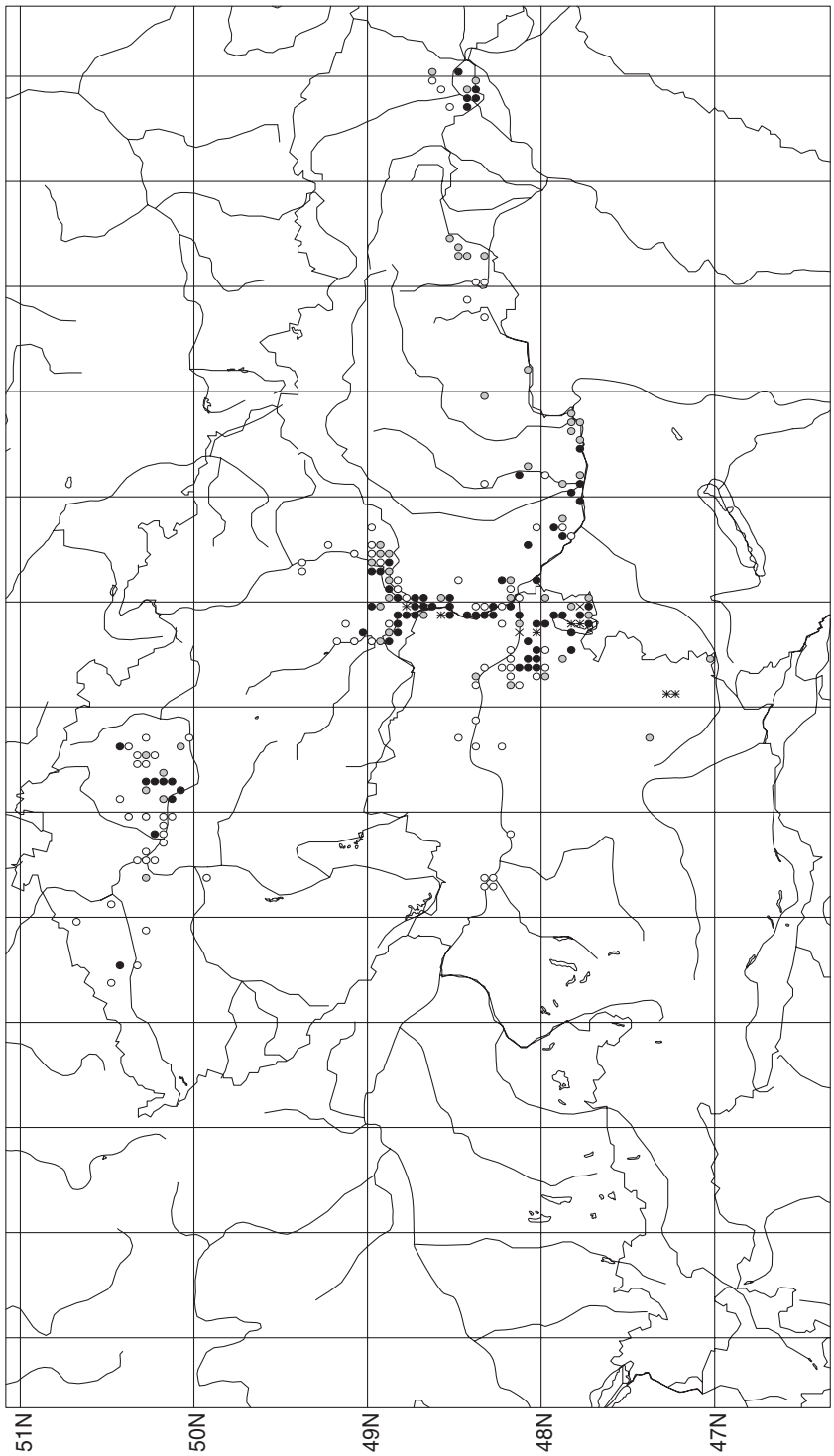

Fig. 2. – Distribution of *Viola pumila* in Austria, Czechia and Slovakia. Symbols: crosses – field records from Mapping the flora of Austria from 1950–1980. For further explanations see captions to Fig. 1.

distribution near the western border of the species' distribution ranges (running through Germany and France) and a distribution not connected with large rivers (Burkart 2001), as observed in Ukraine, southern European Russia and southern Siberia (Meusel et al. 1978, Hultén & Fries 1986).

VS (Fig. 3) occurs mainly along large rivers, the Elbe in central and eastern Bohemia, Dyje/Thaya and Morava/March River in central and southern Moravia, Lower Austria and Slovakia as well as along the Laborec and Bodrog Rivers in eastern Slovakia. However, numerous localities are scattered far from large rivers in eastern and central Bohemia north of the Elbe and in southern Bohemia, in the eastern part of Austria (note also the record from the shores of Lake Constance/ Bodensee in the province of Vorarlberg) as well as in the Záhorie Lowland in western Slovakia. For this reason, VS cannot be considered a river corridor plant in this part of its distribution (see also Zając & Zając 2002). However, it behaves as such along the Danube in Bavaria and the Rhine in Rhineland-Palatinate in Germany (Hauepler & Schönfelder 1988, Eckstein et al. 2006).

The distribution pattern observed corresponds to the ecological profiles of particular species as analysed by Hölzel (2003). VE and VP are confined to base-rich sites. In spring, they require moist or even flooded soils but can withstand long periods of summer drought, which is typical mainly of continental flood-meadows of the *Deschampsion cespitosae* alliance (Hölzel 2003, Černý & Šumberová 2007). Of this species pair, VP seems to be better adapted to summer droughts than VE. Towards the east, the confinement to lowland river corridors disappears, and both species are found in steppe and forest-steppe vegetation, as reported for VP by Becker (1916) and observed by the first author at the northern edge of the Altai Mts. and in the Southern Ural Mts., where VP grows in steppe vegetation with *Stipa capillata* L. and *S. pennata* L. For these reasons, continental climatic conditions seem to be more important for VP and VE than spring floods, which also disturb their habitat. In contrast, VS is not restricted to sites subject to flooding and is probably much less adapted to periods of summer drought. It is usually found growing in the wettest sites on floodplains and on peaty soils, fen meadows and sedge stands away from floodplains, preferably on acidic soils, usually poor in nutrients (Hölzel 2003). Fen meadows and sedge stands are typical of the sites of VS in southern and eastern Bohemia and central Moravia. The rarity of VS in eastern Austria and its absence from some parts of southern Slovakia may be explained by the presence of base-rich substrata there, which originated from the Eastern Alps and the Western Carpathians (Kunský 1968). The regional distribution of VS indicates that this species has a less pronounced affinity for a continental climate, which may be also indicated by its presence in the oceanic parts of northern and western Europe (cf. Eckstein et al. 2006).

The distribution of the violets in Czechia as presented here generally corresponds to that in earlier maps (Kirschner 1983, Slavík 1990, Eckstein et al. 2006). However, moderate corrections were necessary due to re-assessments of some herbarium specimens and the fact that apart from a few recent finds (usually documented by photographs) only records based on herbarium specimens were accepted. Compared with Slavík (1990), changes in the VE map include some additional records mainly from southern Moravia. Major corrections to the distribution map of VS were necessary as some records from northern Bohemia and southern Moravia were not documented by herbarium specimens while others could be added. In Austria, the species' distribution presented here basically matches that in earlier distribution maps (Eckstein et al. 2006), based on preliminary data

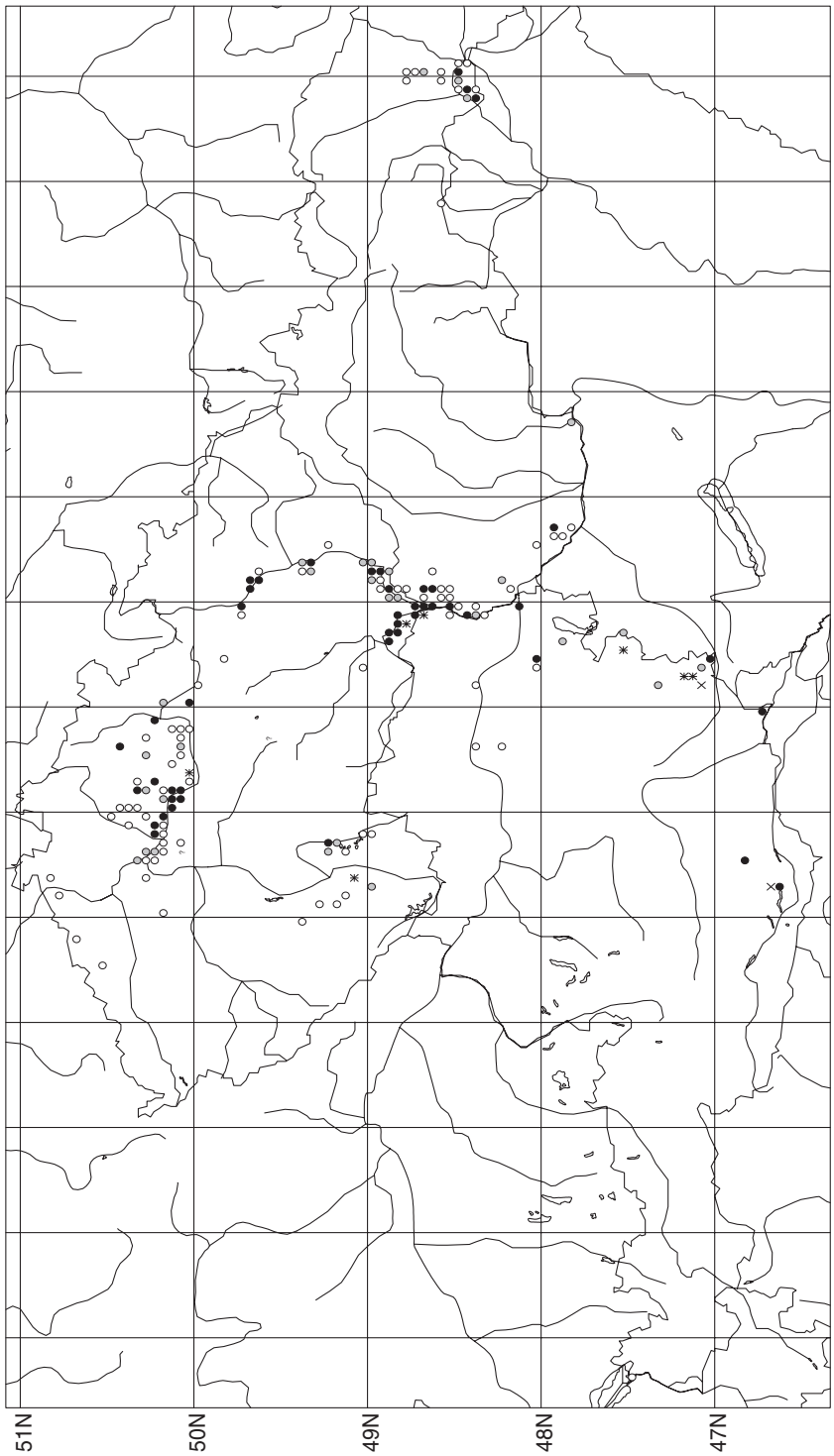

Fig. 3. – Distribution of *Viola stagnina* in Austria, Czechia and Slovakia. For further explanations see captions to Figs 1 and 2.

from herbarium revisions and to some extent also on literature records and unpublished field data. The largest differences exist between the distribution maps of VS as some records were erroneous, based on misidentifications of *V. canina* s.l. and VP. For example, no reliable herbarium specimens of VS were found for Upper Austria (a dubious old herbarium sheet from LI with three species and two labels are not cited in Electronic Appendix 1), and several records from 19th-century floras (cf. Duftschmid 1885) refer mostly to *V. canina* s.l.

Relationships between climate and distribution pattern

The relationships between the density of records and some climatic variables are shown in Figs 4 and 5. VP is the most thermophilous of the three violets, with the highest density of records in the warmest parts of the region studied. In contrast, VS is the least thermophilous of the three with a distinct density peak in regions with a 9–10 °C (Fig. 4) mean annual temperature and 19–20 °C mean July temperature (see Electronic Appendix 2). The pattern in Czechia is similar (not shown) to that in Germany: all records of VE and more than 98% of VP and VS originated from regions with a mean July temperature over 17 °C (cf. Korsch 1999, Hölzel 2003). Most localities of all three species are situated in regions with less than 700 mm average annual precipitation (Fig. 5). However, the records of VE in the Turiec Basin in Slovakia and those of VE and VP in the vicinity of Linz in Austria with a mean annual rainfall of 800–900 mm and those of VE from Arnoldstein in southern Carinthia with a mean annual rainfall 1200–1300 mm are remarkable exceptions.

Changes in frequency in time

The variation in the number of records per year over the period 1831–2000 and the smoothed 11-year moving averages for individual species and countries are shown in Fig. 6 (note different scales for numbers of records). Generally, these curves are not very robust, due to the overall small number of records, and therefore prone to be influenced by accidental events; they can be better understood only if the development of botany in the three countries is considered.

The beginnings of botany in Austria, Bohemia and Moravia, as reflected in the collecting of plants, were similar, though it started one or two decades later in Czechia. Mainly VE and VP were found and collected in the vicinity of Brno, Prague and Linz, and above all in the outskirts of contemporary Vienna (Prater and Brigittenau), with the conspicuous VE collected the earliest. In both countries, collecting flourished from 1881 to 1910. World War I caused some decrease, followed by a recovery mainly in the Bohemian Lands. The political instability in Austria in the 1930s and World War II had a devastating effect on field botany, and virtually no specimens of VE and VS were collected there in the 1940s and early 1950s. A considerable increase occurred in the 1970s when the Mapping the Flora of Austria project started and voucher specimens were collected of species not easy-to-identify in the field. The development in Czechia was different: there was no remarkable decrease between 1939 and 1945 though many sites along the Dyje River in southern Moravia were part of Ostmark and therefore not accessible to Czech botanists. This may be explained by the Recording Action, started by the Czech Botanical Society in 1939 to compensate for the disillusions caused by political developments. A continuous increase after WW II may have been associated with the appointment of professional bota-

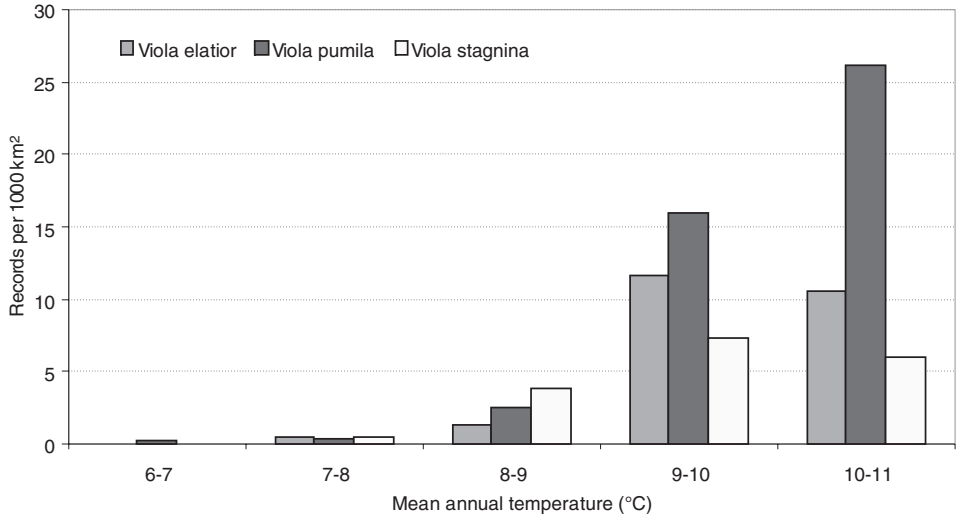

Fig. 4. – Relationship between the numbers of records per 1000 km^2 of *Viola elatior*, *V. pumila* and *V. stagnina* and the mean annual temperature in Austria, Czechia and Slovakia

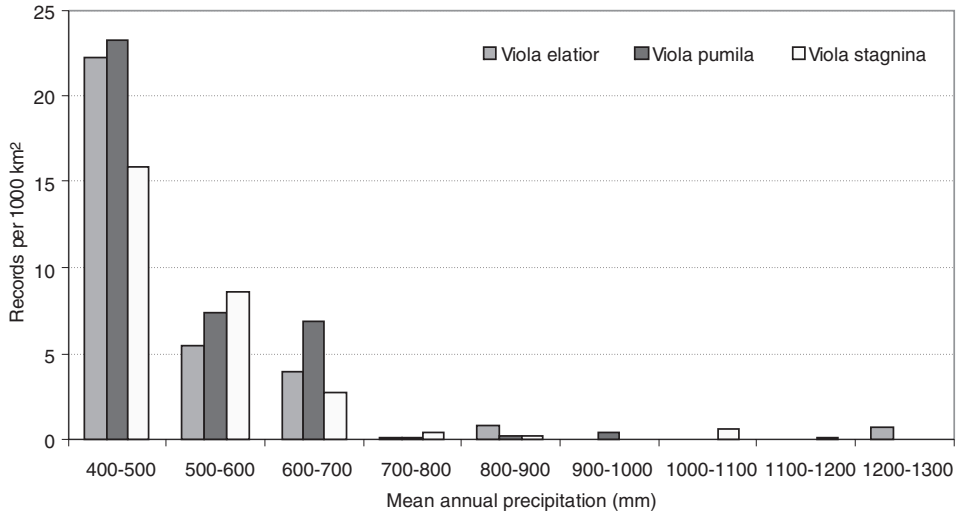

Fig. 5. – Relationship between the numbers of records per 1000 km^2 of *Viola elatior*, *V. pumila* and *V. stagnina* and the mean annual precipitation in Austria, Czechia and Slovakia

nists in the newly established regional museums. The many records in the 1980s may be explained by the revived interest in endangered species after the first version of the Red List of the Czech Flora was published (Holub et al. 1979) and the subsequent collecting activities of V. Grulich, the botanist at the Regional Museum in Mikulov (situated near the sites of all three species), and by accidental events, such as the discovery of a VE population near Uherské Hradiště during the Summer School of Field Botany organized by the Czechoslovak Botanical Society in July 1987. The increase in the 1990s was due to inten-

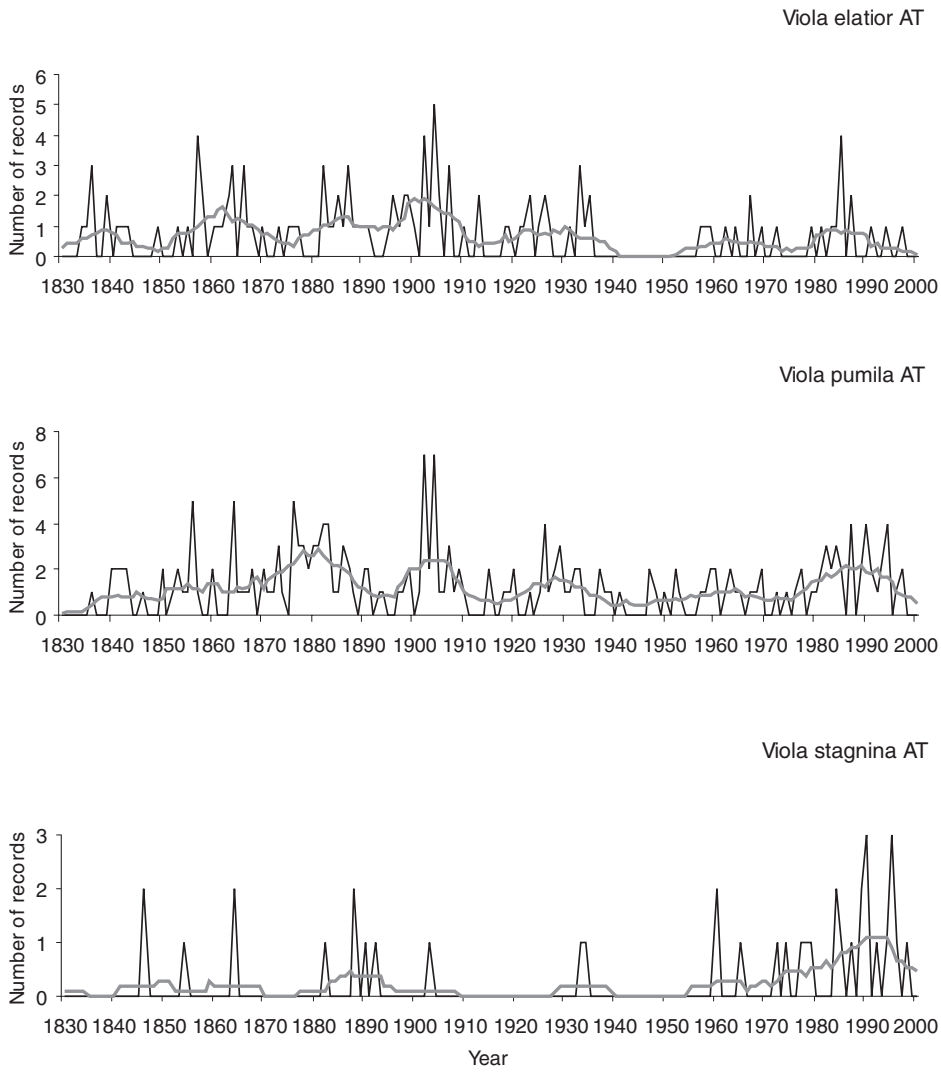

Fig. 6. – Numbers of individual records of *Viola elatior*, *V. pumila* and *V. stagnina* for Austria (AT), Czechia (CZ) and Slovakia (SK) for the period 1831–2000: frequency curves (thin line) and smoothed 11-year moving averages (thick line). Note arbitrary scales for number of records.

sive collecting by the first author and other botanists along the floodplain of the Dyje River, mainly south of Břeclav, which was until 1990 a prohibited zone along the border with Austria. In Slovakia, botanical recording in the 19th century was confined mainly to the surroundings of Bratislava and western Slovakia, and after the establishment of the former Czechoslovakia, Czech botanists focussed on the exploration of the Slovak Carpathians. The research into the flora of southern Slovakia, where the violets occur, started in the 1930s and culminated in the 1950s. It is remarkable that 37 of the 74 herbar-

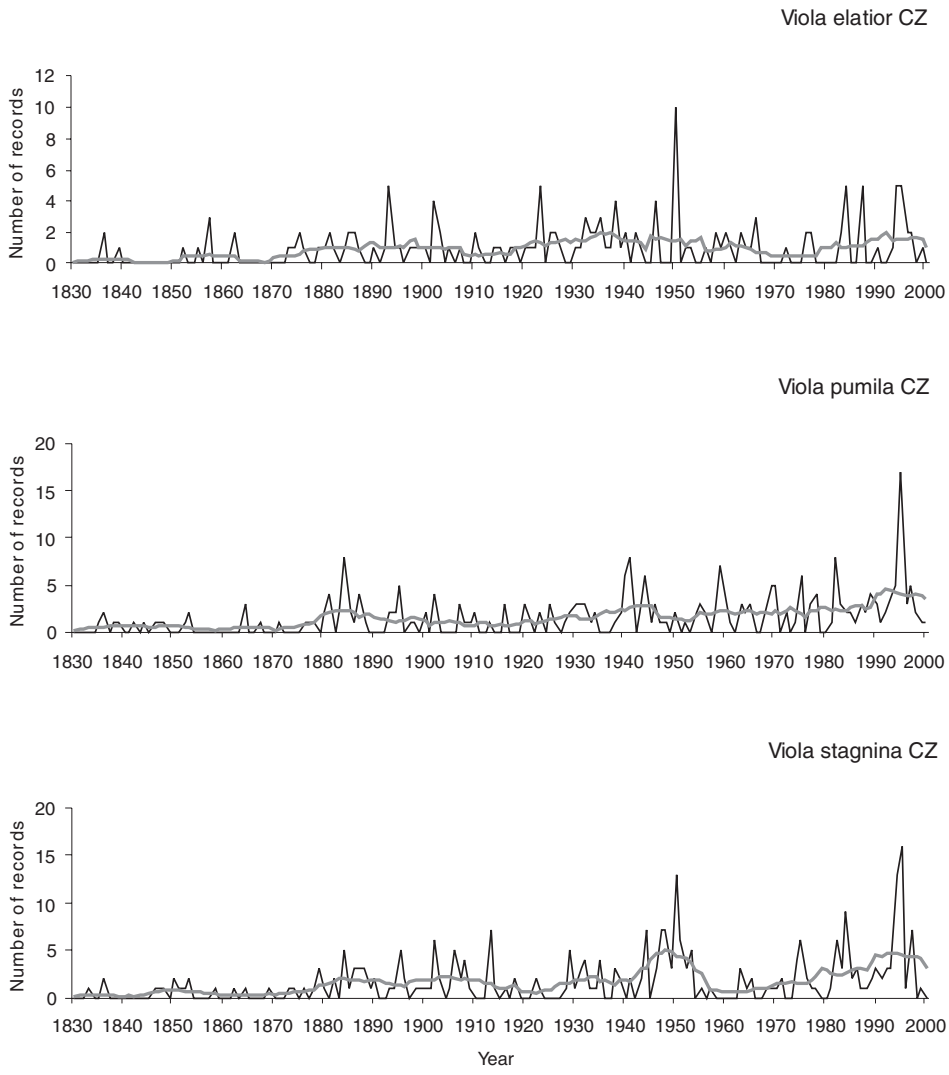

Fig. 6. – Continued.

ium specimens of VS were collected by S. Staněk in 1945–1949, whereas the 10 VP records in May 1981 were made by Czech botanists on an excursion to eastern Slovakia.

There is also some bias in the old Austrian and Czech records of VE: 43 and 18 mainly pre-1850 herbarium specimens from Austria and Czechia, respectively, had no date, so were not included in this analysis. The number of 19th-century records may be underestimated since some old herbarium specimens were destroyed during the wars, thrown away or simply sent to herbaria abroad and not studied by us. Also the number of recent records, mainly those of VE, may be underestimated as field records not documented by a herbarium voucher (often due to conservation concerns) were not included in this analysis. Despite this, all curves can be interpreted as indicating continuous declines in the numbers of

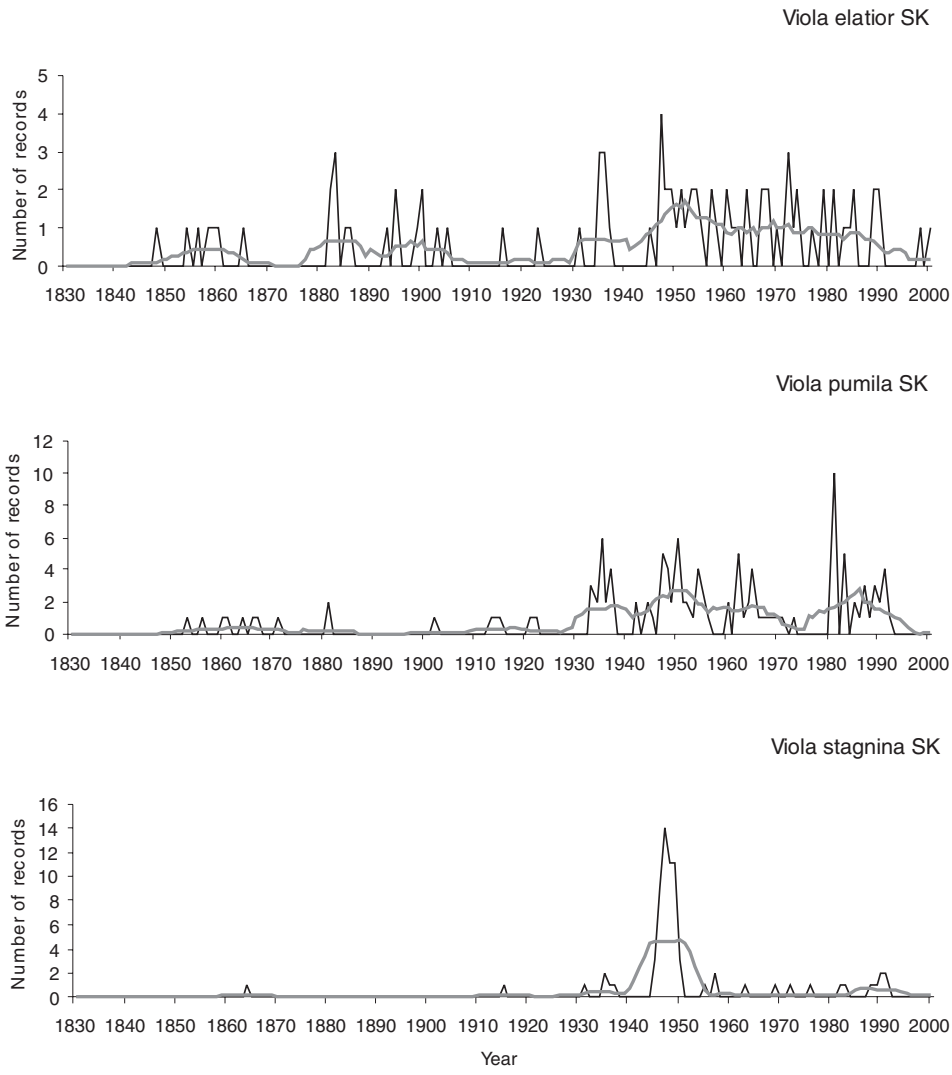

Fig. 6. – Continued.

violets because the number of records remained more or less constant, decreased slightly or increased during the last century, whereas there was a many-fold increase in the number of professional botanists after 1900, and many parts of the country became easily accessible by public or individual transport.

This interpretation is supported if records from Czechia are corrected for the botanical recording activity, based on the temporal distribution of a representative sample of herbarium specimens in Czech public herbaria (Fig. 7): there was a strong decline in VE during the 20th century, and also the patterns for VP and VS indicate a clear decline. The increase in number of herbarium specimens after 1980 may be explained by the circumstances described above.

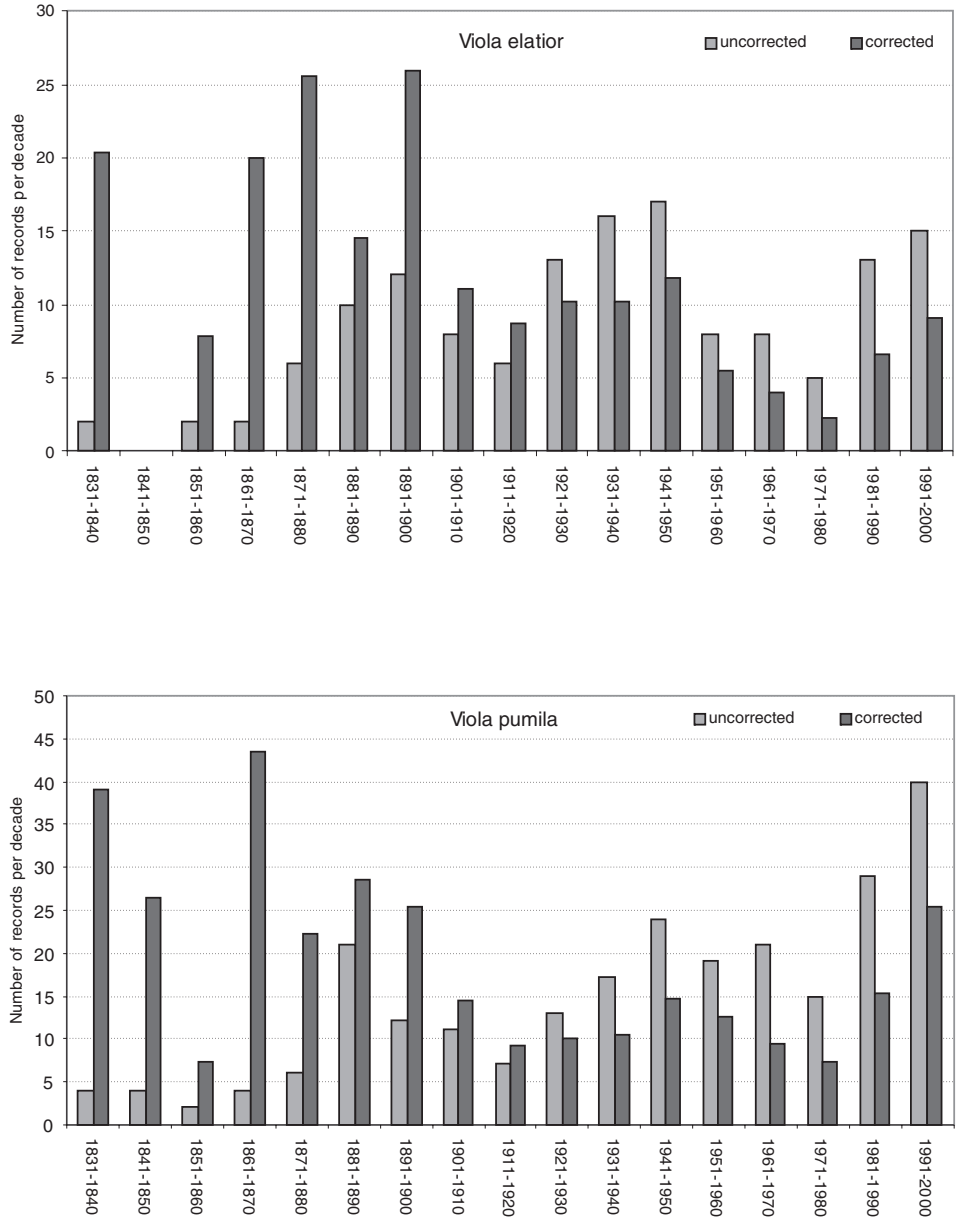

Fig. 7. – Records of *Viola elatior*, *V. pumila* and *V. stagnina* for Czechia for the period 1831–2000 sumarized by decades (specimens deposited in herbaria abroad were not included). Left column: number of records; right column: number of records corrected for the botanical recording activity, based on the temporal distribution of a representative sample of herbarium specimens in Czech public herbaria (J. Danihelka et al., unpubl.)

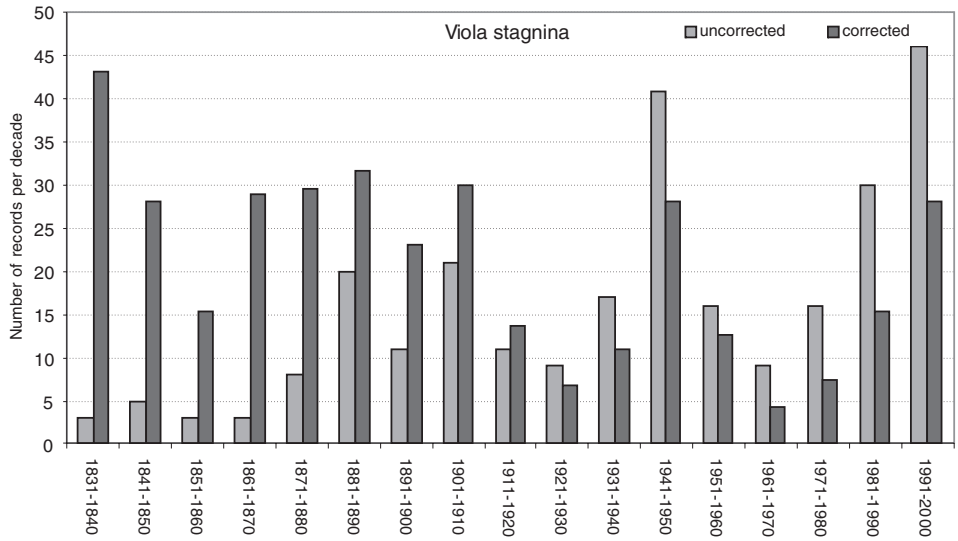

Fig. 7. – Continued.

Changes in number of occupied grid cells are given in Table 2. The situation of the violets is better in Austria than in the other two countries. This is most probably because the changes in land use and agriculture after WW II in Austria were less devastating than in the former Czechoslovakia. The least affected species, declining by 39%, is VE, which grows mainly in ecotone habitats between meadows and floodplain forests or in clearings in alluvial forests. These ecotonal habitats are less influenced by the intensification of agriculture than meadows, which are the predominant habitat of VP (with a 54% decline) and VS (with a 42% decline). In Czechia, the decline ranged between 70% for VE and 67% for VP and VS. Surprisingly, in this country the violets were affected to the same degree regardless of their habitat preferences. The differences between Austria and Czechia seem to be real in spite of the fact that fewer field records were accepted in Czechia. The flora of both countries is well researched, and only a few records from new sites or finds after many years may be expected in future. The (re)discoveries of at least 9 new sites of VP, 19 of VP and 25 of VS, compared with the situation in Czechia as described by Kirschner (1983), cannot be repeated. The decline of the violets in Slovakia was 68% for VP, 75% for VE and 82% for VS. Of the 39 grid cells occupied by VS before 1950 only 7 are still occupied. Actually, it is not possible to determine the accuracy of the Slovakian data: on one hand, the flora of Slovakia is less researched than that of Austria and Czechia, so some new records of the violets may be expected; on the other hand, many populations probably disappeared without being recorded.

Table 2. – Numbers of grid cells with *Viola elatior, V. pumila* and *V. stagnina* in Austria, Czechia and Slovakia. In the last column, percentage of the pre-1950 occurrences confirmed after 1980 is given. Records not documented with herbarium specimens are separated by +; numbers in parentheses with question marks refer to specimens with uncertain localities.

	before 1950	1950–1980	after 1980	after 1980 in %
Viola elatior				
Austria	37 + 17	20 + 17	16 + 17	61.1
Czechia	43 (44?) + 4	17 + 4	10 + 4	29.8
Slovakia	48	33	12	25.0
together	123 (124?) + 21	68 + 21	37 + 21	40.3
Viola pumila				
Austria	62 + 9	39 + 9	27 + 6	46.4
Czechia	81 + 1	42 + 1	26 + 1	32.9
Slovakia	63	42	20	31.7
together	197 + 10	115 + 10	65 + 8	35.3
Viola stagnina				
Austria	18 + 8	13 + 8	9 + 6	57.7
Czechia	99 (101?) + 3	52 + 3	31 + 3	33.3
Slovakia	39	13	7	17.9
together	151 (153?) + 9	74 + 9	45 + 7	32.5

Compared with the figures published by Eckstein et al. (2006), the decline recorded here was stronger. However, the reasons are more methodical than real because: (1) the scale used here was finer than in the previous study, with quarters of basic fields (quadrants) as the recording unit instead of basic fields; (2) occurrences were confirmed after 1980 instead of after 1950. The situation would appear much worse if the number of sites were used as the scale because in some grid cells only one or two sites remain of five or more that existed 50 or 100 years ago. The number of sites would provide the most precise estimate of the real decline, but many old records with little locality information would not be included in the analyses. This approach would also be much more time-consuming. Our decline figures are underestimates because some populations recorded after 1980 and accepted as extant have since been destroyed, such as those of VP and VS flooded by the Nové Mlýny water reservoirs in southern Moravia.

Causes of decline and species status

There are many causes of the decline but they are all connected with human interventions as the majority of the violet populations were found in the most densely inhabited and intensively managed parts of all three countries. Some populations of VE were situated close to the major cities on former floodplains which are now residential or industrial areas: VE in the southern suburbs of Brno was last documented around 1900, in the Brigittenau and Prater of Vienna in 1841 and 1897, respectively, near Linz (now industrial area with steelworks) in 1890. An oil refinery was built at "Vlčie hrdlo" near Bratislava, a site with records for VE from 1848 and 1858. Similarly, VP was last recorded at the southern edge of Brno in 1867, the Prater in 1915 and near Linz in 1878. Many populations might have been destroyed by other changes in land use such as the canalizations of rivers, large-scale drainage and changes in agriculture, e.g. the conversion of alluvial or fen meadows and

pastures into arable land. This development started late in the 19th century and was accelerated after WW II, mainly in the former Czechoslovakia. The remaining fragmented populations are now endangered by abandonment and afforestation, on a herbarium label of VP from Austria termed "Wohlfahrtsaufforstung". The stronger decline of VE in Czechia and Slovakia, a species that often grows in clearings and along tracks in alluvial forests and profits from occasional disturbances, may be explained by the transition from simple coppice forest or coppice forest with standards and occasional grazing into modern forestry where it can hardly survive for 100 years or more (i.e., the usual rotation time) in the soil seed bank under the dense canopy of a high forest.

The status of the violets is different in the three countries: VS is critically endangered in Slovakia both due to strong decline and its original rarity, endangered in Austria because of the small number of sites and only vulnerable in Czechia. Similarly, VE may also be classified as critically endangered in Czechia and Slovakia because of its decline and the few remaining sites, while only vulnerable in Austria. VP is endangered in Czechia and Slovakia, and vulnerable rather than endangered in Austria. However, the poor knowledge of the actual historical distribution and decline rates makes the strict application of the IUCN Red List criteria (IUCN 2003) impossible.

See www.preslia.cz for Electronic Appendices 1 & 2.

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Souhrn

Viola elatior (VE), *V. pumila* (VP) a *V. stagnina* (VS) jsou ve 40 veřejných herbářích v Rakousku, České republice a na Slovensku zastoupeny téměř 1750 doklady pocházejícími z těchto tří zemí. Původní determinace druhu VS a v menší míře VP byly často chybné; vzhledem k tomu a také vzhledem k nomenklatorickým zmatkům, spočívajícím zejména v rozdílném použití jména *V. persicifolia*, jsou literární údaje z 19. století téměř bezcenné. Kříženci jsou obtížně určitelní a vzácnější, než se obvykle předpokládá (nejčastější jsou kříženci druhů VP a VS s druhem *V. canina*). VE a VP se vyznačují podobným rozšířením: jejich výskyt v severní polovině Čech, na jižní a střední Moravě, ve východním Rakousku a na jižním Slovensku je vázán na úvaly velkých nížinných řek a sousední pahorkatiny; rostliny s tímto typem regionálního rozšíření se v německé fytogeografické literatuře označují jako Stromtalpflanzen. VS se od obou zbývajících druhů liší zejména přítomností v jihočeských rybničních pánvích, absencí ve velké části jižního Slovenska, jakož i svou vzácností v Rakousku a na Slovensku. Všechny tři druhy rostou převážně v teplých a suchých částech studovaného regionu: většina lokalit se nachází v oblastech s průměrnou roční teplotou 7–11 °C a průměrným ročním srážkovým úhrnem 401–700 mm. Analýza časového rozložení herbářových dokladů ukázala že všechny tři druhy ustupují v celém regionu: jejich úbytek je nejpomalejší v Rakousku, kde byl jejich výskyt po roce 1980 potvrzen ve 46–61 % kvadrantů síťového mapování (ve srovnání s původním stavem), a nejrychlejší na Slovensku, kde byl jejich výskyt po roce 1980 potvrzen jen v 18–32 % kvadrantů síťového mapování. Hlavní příčinou úbytku jsou regulace řek a následné změny ve využití pozemků (především rozorání lužních luk), jakož

i rozšiřování sídel a průmyslových areálů. VE je pravděpodobně ohrožena také změnami v lesním hospodářství, tj. přechodem od lesa nízkého a středního k lesu vysokému s dlouhou obmýtní dobou a hrubou mozaikou obnovních prvků (rozsáhlé velkoplošné holoseče). Všechny tři druhy jsou oprávněně zahrnuty do národních červených seznamů, byť jejich klasifikace může být v jednotlivých zemích různá; oprávněná a nutná je také jejich zákonná ochrana. Seznam revidovaných herbářových dokladů a vybraných nedoložených terénních nálezů ze všech tří zemí je v elektronickém dodatku.

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