



DEPARTMENT OF BIOLOGICAL AND
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TAXONOMIC OVERVIEW OF COMMON VALERIANS (*VALERIANA OFFICINALIS* AGGR.) IN SWEDEN

A preliminary study



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Figure on frontpage: specimen of *Valeriana sambucifolia* (likely subsp. *salina*),
photographed by the author at Marholmen, Gothenburg

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Abstract

Common valerian (*Valeriana officinalis* L.) is a species of flowering plants native to Europe, the roots of which have been used in folk medicine for centuries. But due to high diversity in morphology and chromosome numbers, different populations in *V. officinalis* sensu lato have been variously treated as their own species, resulting in a complex taxon aggregate. A stable taxonomy with clearly delimited species is important for conservation biology since a species cannot be protected unless it has a name. It is also important for research into the evolution of potentially useful traits in groups of related species. Both of these positives are relevant in the case of plants in the *V. officinalis* aggregate due to their potential for plant-derived medicines. In Sweden, plants in the aggregate are classified into two species (*V. officinalis* sensu stricto, and *Valeriana sambucifolia* J. C. Mikan), with the latter being further split into two subspecies (subsp. *sambucifolia*, and subsp. *salina*). To test this hypothesis, we have performed a preliminary study using collected specimens stored in Herbarium GB. Due to constraints in time and resources no specimens from other herbaria were used, and only quantifiable morphological data was considered. Given that previous taxonomic research had focused on leaf morphology, this became the primary focus. This data was analyzed using the PCA method to summarize the variance amongst examined specimens. In addition, the localities in which the specimens had been collected were used to generate a distribution map for geographic and ecological data. Whilst the limited scope of the study makes the results inconclusive, we found evidence indicating that a taxon considered synonymous to *V. officinalis* sensu stricto (*Valeriana baltica* Pleijel) might represent a distinct species. Further research is needed and would require data from a larger number of specimens as well as molecular data.

Läkevänderot (*Valeriana officinalis* L.) är en art blomväxter, infödda i Europa, vars rötter har använts i folkmedicin i århundraden. Men på grund av stor mångfald i morfologi och kromosomantal har olika populationer av *V. officinalis* sensu lato behandlats som egna arter, vilket har resulterat i ett komplext taxonaggregat. En stabil taxonomi med tydligt avgränsade arter är viktig för bevarandebiologin eftersom en art inte kan skyddas om den inte har ett namn. Det är också viktigt för att förstå evolutionen av potentiellt användbara egenskaper i grupper av nära besläktade arter. Båda dessa positiva effekter är relevanta när det gäller växter i *V. officinalis* aggregatet på grund av deras potential för växtbaserade läkemedel. I Sverige klassificeras växterna totalt in i två arter (*V. officinalis* sensu stricto, och *Valeriana sambucifolia* J. C. Mikan), där den senare delas upp ytterligare i två underarter (subsp. *sambucifolia* och subsp. *salina*). För att testa denna hypotes har vi utfört en förstudie med insamlade prover lagrade i Herbarium GB. På grund av tids- och resursbegränsningar användes inga prover från andra herbarier, och endast kvantifierbara morfologiska data beaktades. Med tanke på att tidigare taxonomisk forskning hade fokuserat på bladmorfologi blev detta det primära fokuset. Dessa data analyserades med PCA-metoden för att sammanfatta variansen bland undersökta prover. Dessutom användes de platser där proverna hade samlats in för att generera en utbredningskarta för geografiska och ekologiska data. Medan studiens begränsade omfattning gör resultaten ofullständiga, fann vi bevis som tyder på att ett taxon som anses synonymt med *V. officinalis* sensu stricto (*Valeriana baltica* Pleijel) kan representera en distinkt art. Ytterligare forskning behövs och skulle kräva data från ett större antal prover samt molekylära data.

Introduction

Valeriana officinalis L. is a flowering plant in the family Caprifoliaceae, the roots of which have been used as a sedative in European folk medicine since ancient times (Christenhusz et al. 2017). However, the taxonomy of *V. officinalis* L. has been contentious due to extreme polymorphism and polyploidy (Titz et al. 1983). A long history of various populations being delimited as distinct taxa of various ranks has led to it being currently characterized as a taxon aggregate referred to as *Valeriana officinalis* agg. (Ghedira et al. 2008). In the Swedish taxonomy database, SLU Artdatabanken, the aggregate includes two species: *Valeriana officinalis* L. (sensu stricto) and *Valeriana sambucifolia* J. C. Mikan ex Pohl; the latter species is in turn divided into two accepted subspecies: subsp. *sambucifolia* and subsp. *salina* (SLU Artdatabanken 2022).

Plants in the *V. officinalis* aggregate typically have imparipinnate leaves, with leaflets that are linear to lanceolate and weakly to strongly serrate. Differences in leaf morphology have been the primary character used to delimit taxa in the aggregate and to enhance identification in the field (Ghedira et al. 2008). In the taxonomic framework accepted by SLU Artdatabanken, the different taxa have been distinguished based on the number, shape, margin, and color of leaflets, as well as the size of the terminal leaflet compared to the rest (Table 1).

In terms of ecology, *V. officinalis* and *V. sambucifolia* subsp. *sambucifolia* grow in similar, inland habitats characterized by soils with high water content, though subsp. *sambucifolia* is far more common and has increased in number over the last century. This increase might be due to increased nitrogen in the environment favoring its growth (Löfgren 2013). In open, coastal habitats, subsp. *sambucifolia* is replaced by subsp. *salina*. In the past, subsp. *salina* has been delimited as a separate species (*Valeriana salina* Pleijel), but a general difficulty in distinguishing it from subsp. *sambucifolia* in the field has led to this hypothesis being largely rejected (Delin et al. 2019).

TABLE 1: comparative leaf morphology of *V. officinalis* aggregate taxa accepted by SLU Artdatabanken based on descriptions in Mossberg et al. 2018 and Delin et al. 2019

Taxon:	<i>V. officinalis</i>	<i>V. sambucifolia</i> subsp. <i>sambucifolia</i>	<i>V. sambucifolia</i> subsp. <i>salina</i>
Leaflet number:	10 pairs	5 pairs	10 pairs
Leaflet shape:	Lanceolate	Lanceolate	Linear
Leaflet margin:	Strongly serrate	Strongly serrate	Weakly serrate
Leaflet color:	Dark green	Light green	Dark green
Terminal leaflet:	Same size	Larger	Larger

An alternative taxonomic framework has been worked out by delimiting taxa in the *V. officinalis* aggregate based on ploidy level. Three major ploidy levels have been observed: diploids, tetraploids, and octoploids. Despite these differences, the monoploid genome at all levels have remained stable at $1n = 7$ (Bressler et al. 2017). Plants in *V. officinalis* s. str. are diploid ($2n = 14$), and most diploid taxa in the aggregate have been classified as either synonymous or infraspecific (Kirschner et al. 2017). Similarly, it has been suggested that octoploid taxa in the aggregate should be classified as synonymous with, or included in, *Valeriana excelsa* Poir. This alternate taxonomic framework has been accepted by most taxonomic databases (Hassler 2004 – 2023; IPNI 2022; Kirschner et al. 2017+; POWO 2022). Out of all the aforementioned databases, only Kirschner et al. 2017+ includes the name *V. sambucifolia* subsp. *salina*. The others instead list the name *V. salina* Pleijel as synonymous with *V. excelsa* subsp. *salina* (Pleijel) Hiitonen. To delimit *V. salina* as subspecific to *V. excelsa* in this

taxonomy based on ploidy level is justified by the fact that *V. salina* has been identified as octoploid in past research (Skalińska 1947).

In order to get a better picture of the taxonomy and history of names in the aggregate, we have conducted a detailed literary review outlined in the section below. These names are listed in SLU Artdatabanken as either accepted or synonymous with the three taxa recognized in the Swedish flora (SLU Artdatabanken 2022). Whilst this is not an exhaustive review of all names associated with the aggregate, they are relevant to this study since it will only focus on the Swedish flora due to constraints in time and resources. For a more complete list, we would direct readers to the database Euro+Med-Plantbase (Kirschner et al. 2017+).

Taxonomic review of relevant names:

Valeriana officinalis L.

Published in 1753 by Carl von Linné, this is chronologically the earliest published taxon in the *V. officinalis* aggregate. Linné placed the genus *Valeriana* in the class *Triandria*, an artificial grouping distinguished by flowers with 3 stamens. *Triandria* is in turn divided into three subgroups based on the number of pistils, with *Valeriana* being placed in *Monogynia* based on its single pistil (Linné et al. 1753). The protologue describes *V. officinalis* L. as follows:

“*VALERIANA floribus triandris, foliis omnibus pinnatis. Habitat in Eurpae nemoribus paludosis*” (VALERIAN with triandrous flowers, all pinnate leaves. It lives in the swampy forests of Europe)

Linné, C. (1753) Classis III.
Triandria. In *Species Plantarum*
(pp. 31–90). Stockholm, Sweden:
Laurentius Salvius.

Assuming that this protologue can be ascribed to *V. officinalis* L. sensu lato, then the description is congruent with our modern understanding of morphology and habitat (Penzkofer et al. 2020). It should be noted however that some sources describe *V. officinalis* L. s. str. as having low shade tolerance and a preference for open habitats (Bertilsson 2003; Ståhl 2016).

The original material used by Linné was from Burser’s plant collection (Hortus Siccus) and was most likely collected close to what is now the border between Germany and the Czech Republic (Kirschner et al. 2007). This material has now been designated as the lectotype by Jan Kirschner, the same author designated the epitype as a specimen collected on August 16, 2006, from the Pisek District in the South Bohemian Region, Czech Republic (Jarvis 2007).

The epitype specimen was found in a wet ditch close to a railway at an altitude of 380 meters, and the leaf morphology appears to match the traits listed in Table 1, except that the



Figure 1: specimen assigned to *Valeriana exaltata*. GB number: 1237–113. Photographed by author.

color is somewhat lighter (Global Plants on JSTOR 2022). Karyological examination of the epitype supports the general consensus that *V. officinalis* s. str. refers to a taxon of diploid plants (Kirschner et al. 2007).

Valeriana exaltata J. C. Mikan ex Pohl

Originally published in 1809, this taxon has often been treated as either synonymous to *Valeriana officinalis* L. (Kirschner et al. 2007) or as an infraspecific taxon. The only valid and legal renaming was published in 1824 with the name *Valeriana officinalis* var. *exaltata* (J. C. Mikan ex Pohl) Kostel (Hassler 2004 – 2023). When the search for the original material referenced in the protologue yielded no results, it was decided to designate as neotype the same specimen designated as the *V. officinalis* L. epitype (Kirschner et al. 2007). Since *V. officinalis* has priority, *V. exaltata* is treated as a synonym (Hassler 2004 – 2023).

Valeriana sambucifolia J. C. Mikan ex Pohl

The lectotype for this name is an illustration from an unpublished iconography by Mikan, which was cited in the original protologue by Pohl in 1809 and is currently stored at the State Library in

Prague. No epitype has been designated since the illustration is detailed enough to give an accurate representation of the morphology (Kirschner et al. 2007).

In contrast with the descriptions given by Mossberg et al. 2018 and Delin et al. 2019, the lectotype has leaves with 2-4 pairs of broadly ovate, dark green leaflets. According to Kirschner et al. 2007, this is the general leaf morphology of all octoploid ($2n = 56$), early flowering, subglabrous, stoloniferous plants in the *V. officinalis* aggregate found in the Jizera Mountains, Krkonoše and Western Carpathians. Since the original protologue referred to the Jizera Mountains as the habitat, the name *V. sambucifolia* J. C. Mikan ex Pohl refers to these plants (Kirschner et al. 2007).

The currently accepted name of this taxon is *Valeriana excelsa* subsp. *sambucifolia* (J. C. Mikan ex Pohl) Holub (Hassler 2004 – 2023; IPNI 2022; Kirschner et al. 2017+; POWO 2022). Like the publication of *V. sambucifolia*, the name change was motivated by the study of plants in Central Europe where hybridization between two octoploid taxa (*V. sambucifolia* and *Valeriana procurrens* Wallr.) resulted in a transitory form. To stabilize the taxonomy, it was recommended to place octoploid taxa as infraspecific to *Valeriana excelsa* Poir., since that name has priority over the other two species names (Holub 1996).



Figure 2: specimen assigned to *Valeriana sambucifolia*. GB number: 1704/557. Photographed by author.

the herbarium specimen designated as the type of *V. excelsa* could belong to any of these subspecies, which would require a name change to *V. excelsa* subsp. *excelsa*. Such a name

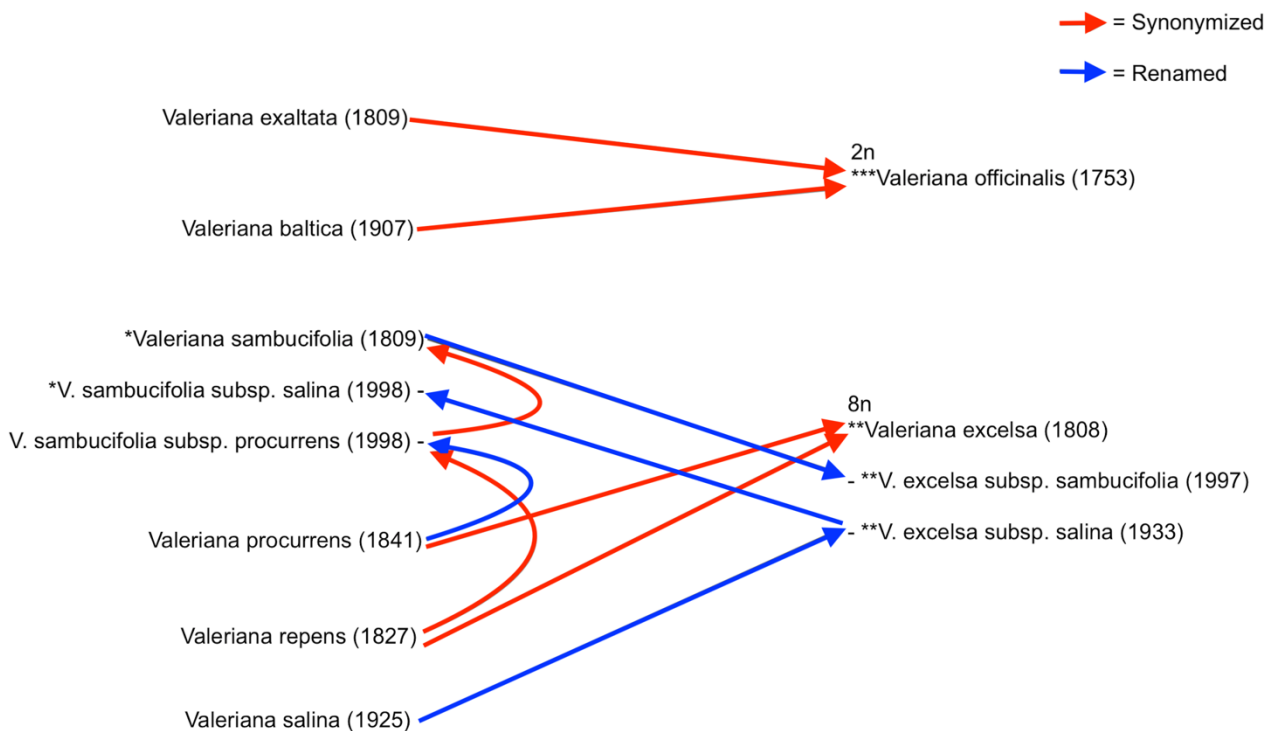


Figure 3: summary of the taxonomic history of the names reviewed in this section. Spelling of names and dates of publication based on POWO 2022 and SLU Artdatabanken 2022. 2n = diploid. 8n = octoploid.

*Name accepted by SLU Artdatabanken 2022

**Name accepted by Hassler 2004 – 2023, Kirschner et al. 2017+, and POWO 2022

***Name universally accepted

change has been implemented in Euro+Med Plantbase, where *V. procurrens* is listed as synonym of subsp. *excelsa*, suggesting that the specimen could be designated as the type of both names (Kirschner et al. 2017+). The original descriptions of *V. excelsa* and *V. procurrens* share some similarities. Both refer to plants with elongate and grooved stems, ovate and distantly toothed lower leaves, lanceolate upper leaves, open panicles, tubular corollas, and ovate seeds that are compressed on the side (Garcke et al. 1840; Lamarck et al. 1809). These traits are similar to the morphology of the *V. sambucifolia* lectotype, including the presence of stolons which are described in the publication of *V. procurrens* (Garcke et al. 1840; Kirschner et al. 2007).

Alternately, *V. procurrens* has been treated as synonymous with *Valeriana repens* Host (Tutin et al. 1976), the original description of which closely resembles that of *V. procurrens* including the presence of stolons (Host 1831). In Flora Europaea 4 it was suggested that *V. repens* might be considered as a subspecies of *V. officinalis* (Tutin et al. 1976), and the name *Valeriana officinalis* subsp. *repens* (Host) O. Bolòs & Vigo was subsequently published in 1983 in Collectanea Botanica (Barcelona) volume 14 (IPNI 2022). But in the Swedish taxonomy, this name is considered synonymous with *Valeriana sambucifolia* subsp. *procurrens* (Karlsson 1998), which was first published in 1970 by Åskell Löve as part of a larger project concerning the Icelandic flora (Löve 1970).

Valeriana sambucifolia subsp. *procurrens* has been used in Swedish taxonomy for years and was distinguished from subsp. *sambucifolia* by its hairier stem and leaves (Mossberg et al. 2018). But recently, subsp. *procurrens* has been deemed synonymous with subsp. *sambucifolia* (SLU Artdatabanken 2022), which could be due to the names having been used interchangeably in various regions with relative uncertainty how to delimit the taxa (Lidberg et al. 2010).

Plants referred to by the name *V. sambucifolia* subsp. *sambucifolia* in the Swedish flora differ from the description of the lectotype given by Kirschner et al. 2017 on three main traits: they flower from May to July, grow in the lowlands (preferring moist soils), and the leaflets are lanceolate. An important trait they share with the lectotype is the presence of stolons,

a trait which is also attributed to the synonyms *V. procurrens* and *V. repens* (Mossberg et al. 2018; Delin et al. 2019). Curiously, SLU Artdatabanken lists *V. excelsa* as synonymous to *V. sambucifolia* (SLU Artdatabanken 2022) when, according to the rules of priority, it should be the other way around. This taxonomic decision was originally published by Karlsson 1998, but the text does not present a reason for the decision.

Valeriana salina Pleijel

Carl Pleijel originally published this name as part of a larger study of bisexual plants of the *V. officinalis* aggregate found in Scandinavia. He recognized two general forms that can be distinguished by the presence/absence of stolons: *V. officinalis* (stolons absent) and *V. excelsa* (stolons present). In addition, he recognized *Valeriana salina* Pleijel as a third form, endemic to the Northern Baltic coastline, and with an ecological preference for rocky shores (Klingstedt 1933). *V. salina* was deemed more similar to *V. excelsa* due to the presence of underground lateral stems terminating in new shoots, and terminal leaflets larger than side-leaflets. *V. salina* could be distinguished from *V. excelsa* by the absence of stolons, and a higher number of leaflets with a narrowly lanceolate morphology and entire margins (Klingstedt 1933).

However, Ilmari Hiitonen argued that *V. salina* should be recognized as a subspecies of *V. excelsa*, giving it the name *V. excelsa* subsp. *salina* (Pleijel) Hiitonen (Klingstedt 1933). This name is accepted by most taxonomic resources (Hassler 2004 – 2023; Kirschner et al. 2017+; POWO 2022), including those that consider *V. excelsa* as synonymous with *V. sambucifolia* (Karlsson 1998; SLU Artdatabanken 2022). The justification given by Hiitonen is that infraspecific taxa adapted to seashore environments are common among many different groups of plants, and that many intermediate forms exist between *V. excelsa* and *V. salina* (Klingstedt 1933). Indeed, widespread hybridization in the wild makes morphological delimitation of the two taxa only possible through pure-bred plants in cultivation. Therefore, it has been suggested that subsp. *salina* should be delimited based on ecological characters rather than morphological (Delin et al. 2019).

If this method of delimitation is implemented, it would mean that Scandinavian plants in the *V. officinalis* aggregate of the *V. excelsa* form (*V. sambucifolia* in Swedish literature) growing in wet soils inland should be referred to as subsp. *sambucifolia*, whilst plants of the same form growing in rocky shorelines should be referred to as subsp. *salina* (Lidberg et al. 2010; Löfgren 2013; Mossberg et al. 2018; Tyler et al. 2007). Strong support for the hypothesis that *V. salina* should be recognized as an ecologically delimited subspecies comes from observations of



Figure 4: specimen assigned to *Valeriana salina*. GB number: 1704/357. Photographed by author.

a continuous, morphological continuum between subsp. *sambucifolia* and subsp. *salina* in wetlands near the coast (Delin et al. 2019).

Valeriana baltica Pleijel

This taxon first appears in the literature in 1831 as an illustration with the name *Valeriana officinalis* var. *simplicifolia* Ledeb., which differs from *V. officinalis* L. by its simple and lanceolate leaves (Ledebour 1831). The illustration was part of a volume publishing illustrations of new and incompletely known plants discovered during research for a complete flora of Russia (Flora Rossica), and the protologue was published years later in the finished work by the same author but with the name changed to *V. officinalis* var. *integrifolia* (Ledebour 1844). *V. officinalis* var. *integrifolia* had originally been illustrated based on plants growing in Livonia, but in 1856 the name was designated to a population of plants growing on the other side of the Baltic in Lusärna, Västervik, Sweden (Lunds botaniska förening 1907).



Figure 5: specimen assigned to *Valeriana baltica*. GB number: 1704/436. Photographed by author.

Carl Pleijel cultivated the Lusärna-form over the course of several years and observed that, apart from the simple leaves, other differences to *V. officinalis* L. included: a more contracted inflorescence with fewer flowers, and a pappus intermediate in morphology between *V. excelsa* and *V. officinalis*. Because these differences were constant through the generations, Pleijel designated the Lusärna form as a separate species with the name *Valeriana baltica* Pleijel. Plants from the same location that showed an intermediate morphology between *V. officinalis* and *V. baltica* were inferred to be hybrids given the presence of both species on the island. Whilst these hybrids varied greatly in the presence and number of leaflets,

they showed a general trend towards reversal to the *V. baltica* morphology (Lunds botaniska förening 1907).

Based on the illustration published in 1831, and descriptions published in the years since, Pleijel designated the name *V. officinalis* var. *integrifolia* as synonymous to *V. baltica*. He did, however, note that the Livonia-form differed from the Lusärna-form by the latter having ovate leaves as opposed to lanceolate. Further inquiry was prevented by the absence of collected specimens and wild plants of the Livonia-form, which Pleijel interpreted as evidence that *V. baltica* might be a rare and possibly declining taxon (Lunds botaniska förening 1907).

Despite this research indicating that the name *V. baltica* refers to a distinct taxon, most taxonomic sources list *V. baltica* as synonymous with *V. officinalis* (Hassler 2004 – 2023; Karlsson 1998; Kirschner et al. 2017+; POWO 2022; SLU Artdatabanken 2022). This might be influenced by research on diploid plants belonging to the *V. officinalis* aggregate in Central Europe, which has concluded that all diploids in the complex should be included in *V. officinalis*

s. str. (Kirschner et al. 2017). It is unclear if the same standard should be applied to plants in Northern Europe, especially since *V. officinalis* is characterized as having leaves divided into leaflets (Mossberg et al. 2018).

With this long and complicated history in mind, we have decided to test the current taxonomic hypothesis concerning plants of the *V. officinalis* aggregate found in the Swedish flora. This study will, due to constraints, only be a preliminary investigation focusing mainly on differences in leaf morphology through morphometric analysis. It should be noted that the absence of molecular data in this study does not undermine its validity, as comparative morphology of vegetative and reproductive characters has yielded valuable results in studies focused on the systematics of closely related taxa in groups with complicated taxonomy (Kirschner et al. 2017, 2020; Štěpánek et al. 2022).

Efforts to improve our understanding of plant taxonomy is of great value to many fields of biology as it allows for a clearer understanding of biodiversity as well as the evolution, distribution, and conservation of species (Grace et al. 2021). We are currently going through a time of significant ecological changes and the mapping of biodiversity is more important than ever before. Poorly resolved taxonomy hampers conservation efforts since we need clearly delimited species in order to assess their risk of extinction. Also, the potential medicinal value of plants in the *V. officinalis* aggregate could make them relevant in studies concerning the evolution of useful traits, which could in turn allow for the identification of new crops and their wild relatives (Grace et al. 2021).

Aim

To do a preliminary investigation of the delimitation of taxa in the Swedish flora belonging to the *Valeriana officinalis* aggregate based on quantitative, morphological characters. Null hypothesis is that the currently accepted taxonomy is correct.

Material and method

Specimens:

For the collection of data, we chose to focus on herbarium specimens. Due to time constraints, our selection was limited to herbarium specimens stored in the herbarium of the University of Gothenburg (Herbarium GB). A total of 86 specimens were used that had been assigned to the following taxa:

- *Valeriana baltica* Pleijel
- *Valeriana baltica* x *exaltata*
- *Valeriana exaltata* J. C. Mikan ex Pohl
- *Valeriana exaltata* x *sambucifolia*
- *Valeriana salina* Pleijel
- *Valeriana sambucifolia* J. C. Mikan ex Pohl

Since the aim was to investigate the delimitation of taxa, it was important to include hybrids whenever possible. To simplify the data processing, each specimen was assigned an arbitrary number from 1 to 86. It should be noted that most of the specimens had undergone reassignment to various taxa in the past but had each been stored in a folder based on the currently assigned taxon. The name on the folder is what we looked at and recorded in our register of examined specimens (Table 2).

TABLE 2: list of herbarium specimens. Each specimen was assigned a number (1–86) to which it was subsequently referred to in the analysis.

Assigned taxon:	GB nr:	Assigned number:
<i>Valeriana baltica</i>	1237–108	1
	1237–105	2
	1266–5	3
	1704/433	4
	1704/436	5
	1704/437	6
	1704/435	7
	1704/434	8
	1704/493	9
	1237–186	10
<i>Valeriana baltica</i> x <i>exaltata</i>	1266–4	11
	1237–107	12
	1704/469	13
	1237–106	14
<i>Valeriana exaltata</i>	1704/306	15
	1237–110	16
	1704/311	17
	1704/305	18
	1704/303	19
	1704/308	20
	1704/422	21
	* 25 juli 1961 (Knut Egeröd)	22
	* 17 juni 1961 (Knut Egeröd)	23
	1704/315	24
	1704/312	25
	1704/314	26
	1704/313	27
	1704/451	28
	1704/316	29
	1704/320	30
	1237–114	31

	1237–113	32
	1237–112	33
	1237–111	34
	1704/319	35
	1704/317	36
	1704/318	37
	1704/324	38
	1704/321	39
	1704/323	40
	1704/327	41
	1704/326	42
	1704/322	43
	1704/325	44
<i>Valeriana exaltata</i> x <i>sambucifolia</i>	1704/429	45
	1704/428	46
	1704/422	47
<i>Valeriana salina</i>	1704/272	48
	1704/332	49
	1704/339	50
	1704/351	51
	1704/356	52
	1704/370	53
	1704/522	54
	1704/502	55
	1704/489	56
	1704/490	57
	1704/357	58
	1704/393	59
	1704/568	60
	1704/274	61
	1704/400	62
	1704/401	63
	1704/273	64
	1704/398	65

	1704/284	66
<i>Valeriana sambucifolia</i>	1704/525	67
	1704/527	68
	1704/529	69
	1704/526	70
	1704/528	71
	1237–138	72
	1704/379	73
	1704/541	74
*	1 juli 1934 (Birgit Karlsson)	75
	1704/542	76
	1704/543	77
	1704/545	78
	1704/546	79
	1704/547	80
	1704/548	81
	1704/549	82
	1704/550	83
	1704/551	84
	1704/557	85
	1704/556	86

GB = Gothenburg (Herbarium GB)

* Specimen lacked a GB number; date of collection and name of collector was listed instead.

Data collecting and analysis:

The following traits were quantified:

- Length of terminal leaflets
- Width of terminal leaflets
- Length of lateral leaflets
- Width of lateral leaflets
- Number of leaflets

Measurements of length and width were done with a simple ruler, and the data was compiled in an excel-file. An issue that needs to be addressed however, is that all specimens of *V. baltica* (except for 1704/493) lack any side leaflets and have simple leaves. To simplify the analysis, the length and width of their simple leaves was quantified as the length and width of their terminal leaflets, the lack of any side leaflets was quantified by assigning the value of zero to these traits. In addition to quantitative characters, the overall morphology of leaflets and leaflet margins were recorded as binary:

- 0 = strongly serrate margins/lanceolate leaflet shape
- 1 = weakly serrate margins/linear leaflet shape

To process the data, a Principal Component Analysis (PCA) was performed using the program R. PCA is a statistical analysis which sorts out the dimensions (components) that best capture the variance in a dataset. In a 2-dimensional graph, the components can be visualized as an X-axis (1st dimension) and a Y-axis (2nd dimension) intersecting at a mid-point (hereafter referred to as the origo). Data points in the graph are interpreted based on how they cluster around the components and the origo (Ngo 2018). In our analysis, each data point is numbered based on the arbitrary number assigned to each herbarium specimen. This allowed us to more easily identify which data points corresponded to what taxon, aiding in our interpretation of the results.

An additional source of information is the cos2-value (squared coordinates) assigned to the data points. These values derive from the fact that each data point is derived from multiple variables, each one contributing to the variance the component needs to capture. Some variables have higher weight (contributes more to the variance) than others, this is calculated as cos2-values and can be visualized as different colored data points. Ultimately, both cos2-values and components need to be considered when interpreting the data (Kassambara 2017).

In addition to quantitative data, geographic data was also used. Each locality where the specimens had been collected were mapped out on the free website [MapCustomizer.com](https://www.mapcustomizer.com), which can be used to generate simple maps by pinpointing locations. It should be noted that some localities were more specific than others depending on the collector's notes, but a general distribution can still be discerned and used in the final discussion.

It needs to be mentioned that, unfortunately, the qualitative data concerning the leaf margins as well as the number of leaflets had to be excluded from the PCA. This was because they were not measured with the same units as the size of leaflets (in millimeters) and led to the results being more difficult to interpret. Focusing on the size of leaflets allowed for clearer results and a more straightforward interpretation. If we were to perform this analysis again, we might use a different way to measure the quantifiable data.

Results

Principal Component Analysis:

Depending on the data analyzed, the PCA can recover any number of principal components that capture the variance. In this case, 4 were recovered that together captured 100%. Of these 4, the 1st was by far the most significant as it described ca 79%. This was followed by a drop to 10.6% in the 2nd component, and 8.2% in the 3rd. The remaining 2.2% was captured by the 4th component.

TABLE 3: summary of the principal components recovered from the analysis, and how much each component describes the variance in the dataset.

	EIGEN VALUE	VARIANCE %	CUMULATIVE %
DIM.1	3.159	78.969	78.969
DIM.2	0.426	10.648	89.617
DIM.3	0.329	8.220	97.837
DIM.4	0.086	2.163	100.000

Note: values rounded to the third decimal place.

DIM = dimension (component).

Since the first two components capture 90%, the variance in the dataset could be plotted in 2 dimensions where specimens are clustered together based on how significant their morphological similarities are deemed by the analysis and colored according to their cos2-values (Figure 6). In the resulting plot there is a clear supercluster of specimens with uniformly high cos2-values, most of which are assigned to *V. exaltata* and related hybrids. Specimens assigned to any of the other three taxa cluster either outside or at the periphery of the supercluster.

V. baltica have the least overlap with the other taxa. Specimens 3–5 stand out in being isolated on the plot whilst retaining high cos2-values. In contrast, related specimens with similarly high values are placed within or around the supercluster close to hybrids with *V. exaltata*. *V. sambucifolia* clusters in a similar manner, with a relatively isolated cluster of specimens and a smaller cluster within the supercluster. This taxon also has the most specimens with low cos2-values that cluster around the origo, where it overlaps with *V. salina*. *V. salina* overlaps with both *V. sambucifolia* and *V. exaltata*. Specimens 57, 48, and 61 are closer to a small cluster of *V. exaltata* located outside the supercluster. Two notable outliers are specimens 62 and 63, the latter of which has the lowest cos2-value of any specimen in the plot.

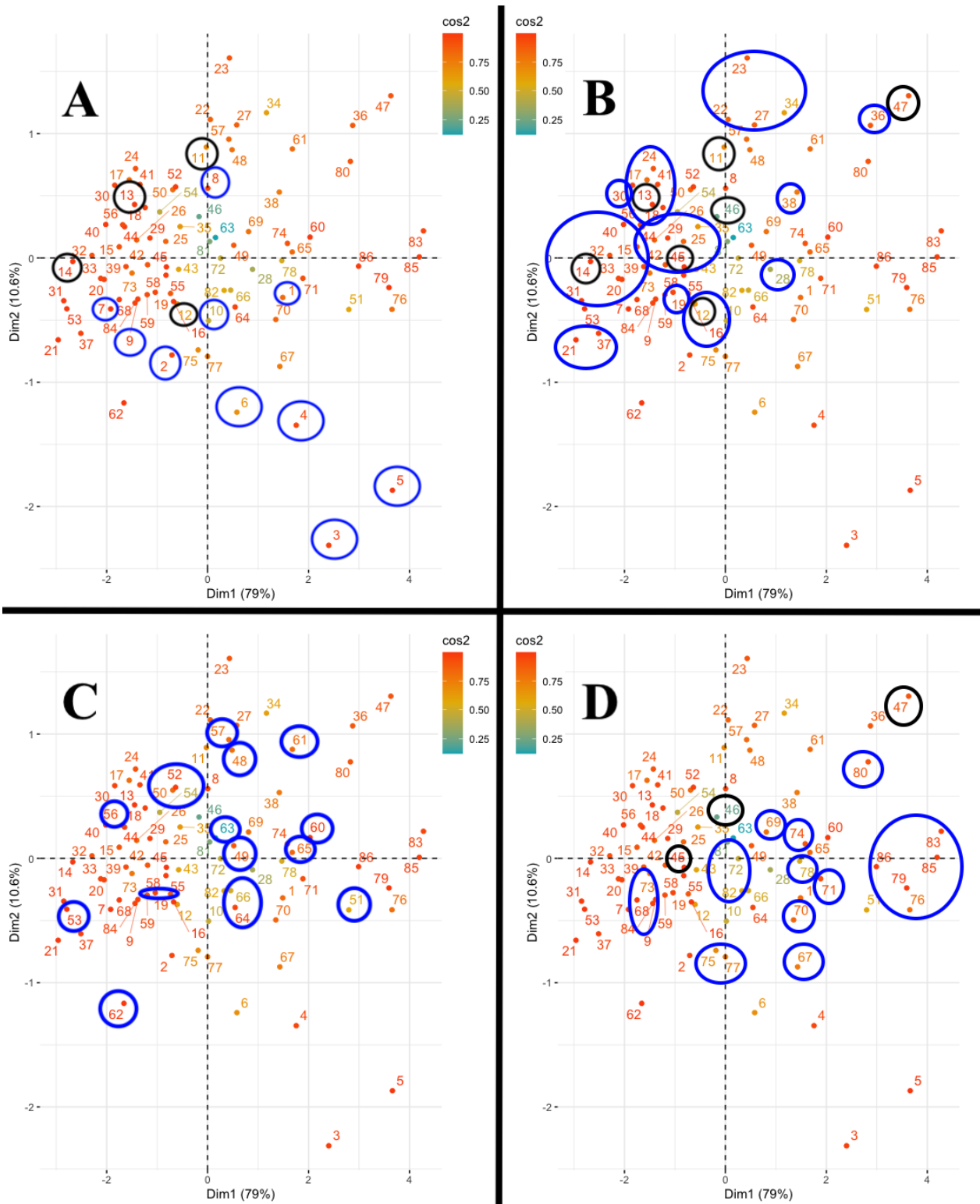


Figure 6: PCA plots of herbarium specimens. Numbered datapoints correspond to quantitative data collected from a single specimen (see Table 2 for corresponding GB numbers). Datapoints colored according to cos^2 -value. X-axis represents Dimension 1 (79% variance capture), Y-axis represents Dimension 2 (10.6% variance capture). Rings drawn to distinguish relevant taxon in each plot (A: *Valeriana baltica* Pleijel; B: *Valeriana exaltata* J. C. Mikan ex Pohl; C: *Valeriana salina* Pleijel; D: *Valeriana sambucifolia* J. C. Mikan ex Pohl.), black rings drawn around hybrid specimens.

An interesting outlier is specimen 47, a hybrid of *V. exaltata* and *V. sambucifolia* in close proximity to two specimens assigned to both parent taxa, along with specimen 61 assigned to *V. salina*. All these specimens appear to have similar cos^2 -values slightly above 0.75.

Explanation of cos2-values:

In order to fully understand what exactly the PCA is capturing, we needed to look at the loading of each specific variable on the component. The magnitude of the loading is referred to as the “contribution” of each variable. In the first component, each variable’s contribution was within the range of the expected average (Figure 7). This probably means that differences in how much each variable contributes was mainly due to differences in the measurements themselves.

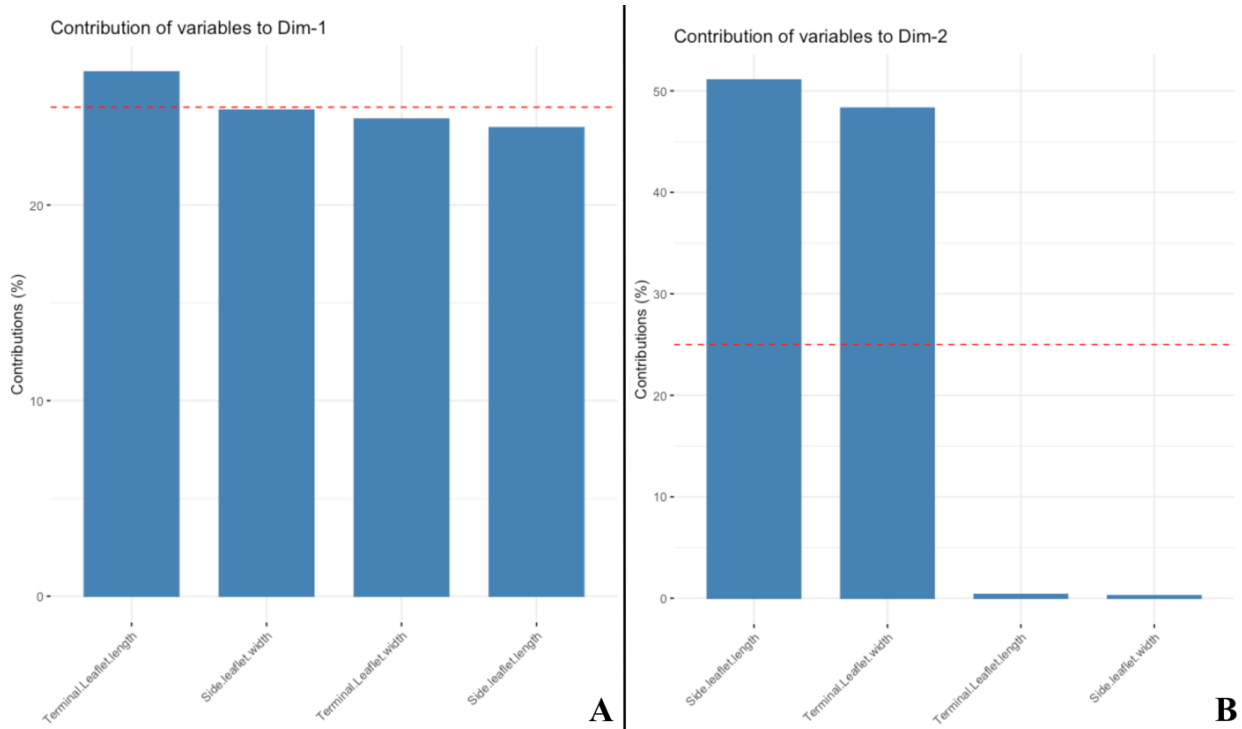


Figure 7: graphs illustrating the percentwise contribution of each variable to the 1st component (graph A) and the 2nd component (graph B). Red, dashed line indicates the expected average contribution of all variables. Dim = dimension (component).

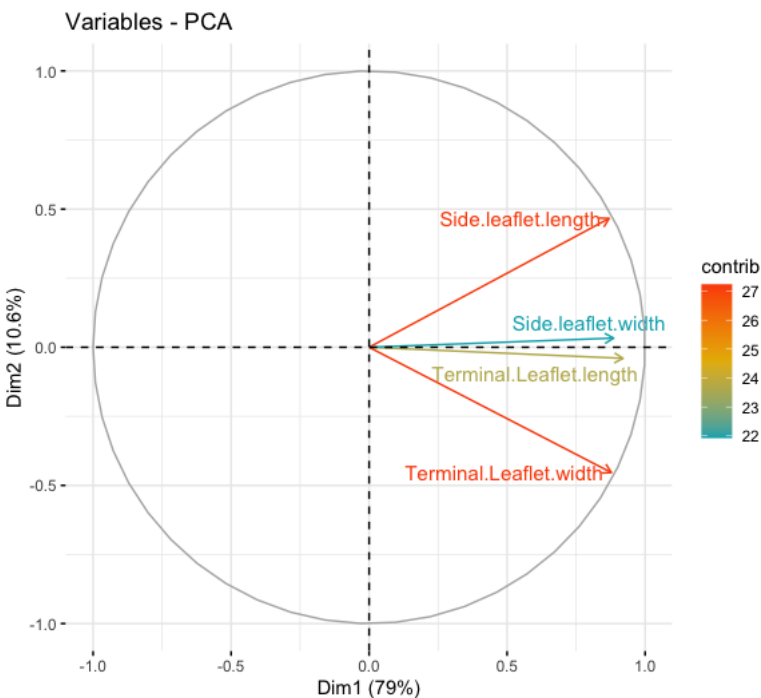


Figure 8: factor map of variables. The closer each arrow is to the circle, the better represented they are in the PCA. Positive correlation is indicated by the placement of all arrows to the right of the circle. Dim = dimension (component).

But, in the second component, there was a rise in the contribution of the variables “side leaflet length” and “terminal leaflet length” that went far above average, with the other variables barely contributing. This indicated that these two variables had a much higher loading on the components in the PCA and would therefore have a higher cos2-value.

To get a clearer picture of the cos2-values of each variable, a factor map was generated where the variables are clustered according to how they correlate with each component and with each other. In the resulting factor map, the two highest contributing variables in the second component did indeed have the highest cos2-values and were positively correlated with the other

variables. It also shows that, whilst the variables contribute differently, they are all positively correlated with both components (Figure 8).

Geographic distribution:

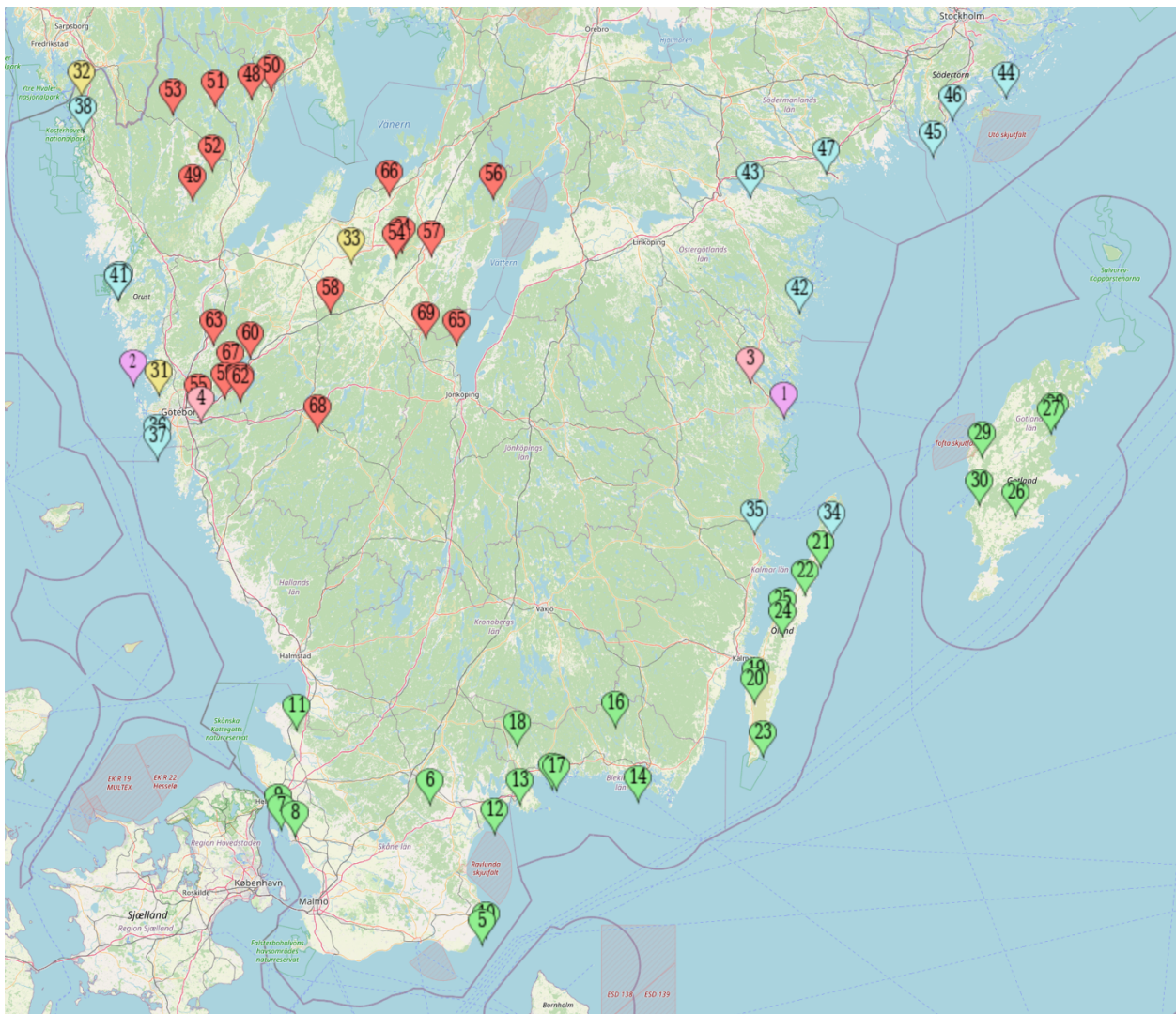


Figure 9: distribution map based on herbarium specimen locality. Map markers numbered and colored according to assigned taxon. 1–2 (Purple): *Valeriana baltica*. 3–4 (Pink): *Valeriana baltica* x *exaltata*. 5–30 (Green): *Valeriana exaltata*. 31–33 (Yellow): *Valeriana exaltata* x *sambucifolia*. 34–47 (Blue): *Valeriana salina*. 48–69 (Red): *Valeriana sambucifolia*.

The resulting distribution map shows that all examined specimens were collected in Sweden, specifically Götaland, southern Svealand, Öland, and Gotland (Figure 9). What is particularly noteworthy is that all specimens assigned to *V. baltica* were either collected in Lusärna, Västervik, or were cultivated from plants growing in Västervik. Plants grown from seeds collected from Lusärna were referenced in the original description of *V. baltica* (Lunds botaniska förening 1907). The only exception is specimen 1704/493 which was collected from Marstrand, Kungälv, in western Götaland. One specimen (1266–4) designated as a hybrid with *V. exaltata* was also collected from Lusärna, the other hybrids were collected from Gamleby (1237–107), Partille (1704/469), and a cultivated specimen from Hortus Bergianus (1237–106).

Specimens assigned to *V. salina* follow a predictably coastal distribution along both the west and east coast. Whilst most of the notes left by collectors only provide general locations with no description of the habitat, the few that do describe *V. salina* as growing on headlands, islands, and coves. One specimen (1704/274) was collected on a gravelly beach in Ornö, another (1704/490) from a small coastal plain in Fiskebäckskil. These noted habitats and localities appear

to match the literature concerning this taxon’s ecological preferences and distribution (Lidberg et al. 2010; Mossberg et al. 2018).

The distribution of *V. sambucifolia* specimens is limited to north-western Götaland, with several localities close to the great lakes Vänern and Vättern. Specimens 1704/528 and 1704/557 were collected by a riverside and stream edge respectively, and specimen 1704/529 was collected in a wet meadow in Öjersbyn. A hybrid with *V. exaltata*, 1704/422, was also collected by a stream edge. In the literature, these habitats are mentioned among many others (Lidberg et al. 2010; Mossberg et al. 2018).

V. exaltata shows a distribution mainly around the coast of Scania and Blekinge, with only three inland localities. A large number of specimens were also collected from the large islands Öland and Gotland, with the only other taxon collected from these islands being *V. salina* (specifically specimen 1704/272). Noted habitats include trenches (1704/306 & 1237–111), open grassland (1237–114 & 1237–113), shady grassland (1237–112), marshland (1704/451), and coastal plains (specimens 22 & 23 [Table 2]). The literature does list these habitats for the synonymous taxon *V. officinalis*, which also describes *V. officinalis* as growing mainly in southern Sweden closer to the coasts (Lidberg et al. 2010; Mossberg et al. 2018).

Discussion

Resurrection of *Valeriana baltica* Pleijel?

According to the cos2-values, the width of the terminal leaflet and the length of the side leaflet are the most informative variables (Fig. 4). A simple scatter plot of these two values (Fig. 6) shows a large difference between *V. baltica* and the other taxa, which is that most *V. baltica* specimens cluster at 0 on the side leaflet axis.

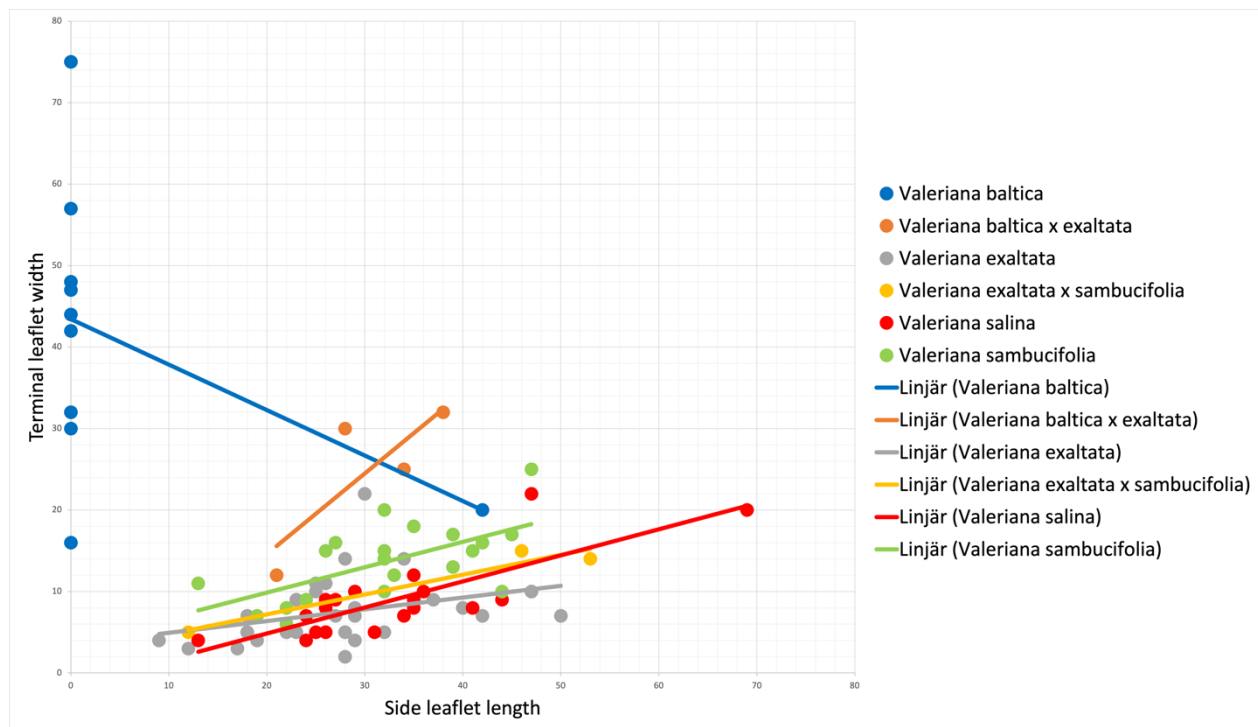


Figure 10: plot generated using excel comparing the width of the terminal leaflet (Y-axis) and length of the side leaflet (X-axis) in all specimens. Lines and dots colored according to assigned taxon. Linjär: Swedish for “linear.”

The reason for this distribution is the fact that nearly all specimens of *V. baltica* only have simple leaves and lack compound leaves, a distinctive trait that has been described in previous research (Ledebour 1831; Lunds botaniska förening 1907). This raises the possibility that the presence/absence of side leaflets in the first place has affected the cos2-values and the distribution of specimens in the PCA plot. That perhaps the reason why the two most informative

variables come down to a comparison between terminal leaflets and side leaflets is because specimens with simple leaves were quantified as having only terminal leaflets, and the variables concerning side leaflets were quantified as zero. Whilst this might question the reliability of the results, it could also point to an underlying reality: the very fact that *V. baltica* has simple leaves might justify recognizing it as a distinct taxon, and not a synonym of *V. officinalis*.



Figure 11: specimens assigned to *V. baltica* (left) and *V. exaltata* (right). GB number of top specimens: 1266–5 (far left), 1704/436 (center left), 1237–111 (center right), 1704/317 (far right). GB number of bottom specimens: 1704/435 (far left), 1704/493 (center left), 1237–113 (center right), 1237–112 (far right). Photographed by author.

Considering that specimens assigned to *V. officinalis* were not included in the analysis, and that *V. exaltata* is a homotypic synonym of *V. officinalis* (Kirschner et al. 2007), we will for this study accept the synonymy of *V. exaltata* and interpret the results accordingly.

Looking at the PCA plot (Figure 6) the *V. baltica* specimens furthest from the *V. exaltata* supercluster are 1266–5 and 1704/436 (assigned numbers 3 and 5), and those deepest within the supercluster are specimens 1704/435 and 1704/493 (assigned numbers 7 and 9). All these specimens have simple, ovate leaves, except for 1704/493 which has compound leaves divided into three ovate leaflets (Figure 11, left). This particular specimen was also the only one collected on the west coast (Figure 9) and was originally identified as *V. excelsa* (later changed to *V. sambucifolia*), which raises the question if maybe the designation as *V. baltica* is a case of misidentification. It might be worthwhile to try and analyze the specimens excluding 1704/493, unfortunately it is not within the scope of time for this study.

In contrast, specimens of *V. exaltata* have compound leaves with numerous leaflets that are either linear or lanceolate. Looking at the PCA plot (Figure 6), this general morphology seems to apply to both specimens within the supercluster (Figure 11, bottom right [assigned numbers 32 and 33]) and outside it (Figure 11, top right [assigned numbers 34 and 36]).



Figure 12: specimens assigned to *V. salina* (left) and *V. sambucifolia* (right). GB number of top specimens: 1704/357 (far left), 1704/393 (center left), 1704/551 (center right), 1704/557 (far right). GB number of bottom specimens: 1704/400 (far left), 1704/401 (center left), 1704/548 (center right), 1704/549 (far right). Photographed by author.

The same morphology is found in the neotype (Global Plants on JSTOR 2022) and is also what is described in the literature under the name *V. officinalis* (Mossberg et al. 2018; Penzkofer et al. 2020). We can therefore be fairly confident that the supercluster on the plot corresponds to specimens with the *V. officinalis* morphology, and that *V. baltica* (having the least overlap) differs the most from *V. officinalis*. The collection of specimens includes some designated as hybrids between *V. baltica* and *V. exaltata*. The terminal leaflets of these specimens do still exceed that of most others (Figure 10), but these results might not be reliable since we only had four such specimens available for the analysis. One of these presumed hybrids (1704/469) was originally identified as *V. sambucifolia*, and the specimens in question appear similar in leaf morphology to the *V. sambucifolia* lectotype (Kirschner et al. 2007) but with larger terminal leaflets. If hybridization with *V. officinalis* (= *V. exaltata*) is common, resurrecting *V. baltica* as an infraspecific taxon, as it had been originally (Ledebour 1831), could be preferable.

The delimitation of *Valeriana salina* Pleijel:

Morphology

Previous research has supported the recognition of *V. salina* as an infraspecific taxon due to widespread hybridization being inferred from multiple intermediate forms in the wild, as well as cultivation experiments showing reproductive compatibility (Klingstedt 1933; Delin et al. 2019). In our analysis, we were unable to find contradicting evidence. Whilst *V. sambucifolia* does form a small cluster outside the *V. exaltata* supercluster, no similar clustering occurred for *V. salina*, which instead seems dispersed on the PCA plot between the two taxa (Figure 6). A possible reason for this dispersed pattern is that the leaf morphology of specimens designated as *V. salina* do resemble that of *V. officinalis* (= *V. exaltata*) with several pairs of linear to lanceolate leaflets (Figure 12, left), which is also similar to the morphology of cultivated *V. salina* plants (Delin et al. 2019).

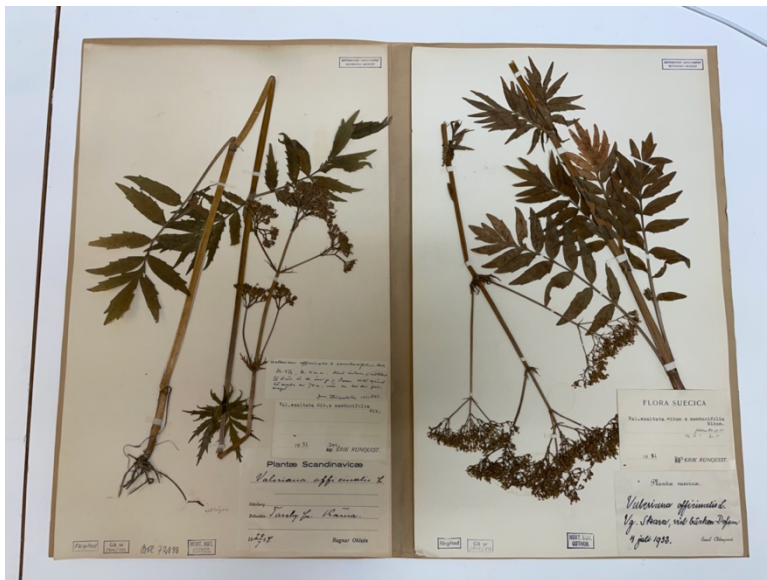


Figure 13: specimens designated as hybrids between *V. exaltata* and *V. sambucifolia*. GB numbers: 1704/429 (left), 1704/422 (right). Photographed by author.

Notably, specimens designated as *V. sambucifolia* have fewer pairs of leaflets compared to the other taxa, and many have distinctly ovate leaflets. This matches the leaf morphology of the lectotype (Kirschner et al. 2007) and can be found in specimens that are either in the small *V. sambucifolia* cluster (Figure 12, top far right [assigned number 85]) or in the supercluster (Figure 12, top center right [assigned number 84]). Many specimens of *V. sambucifolia* (such as 1704/557 and 1704/549) also have strongly serrate leaflet margins like those of cultivated plants (Delin et al. 2019).

In-between the clusters, specimens of *V. salina* and *V. sambucifolia* with low \cos^2 -values overlap. These specimens probably have lower \cos^2 -values because the opposite variables (terminal leaflet length and side leaflet width) contribute more to their position on the plot than the other variables. Whilst these values explain less of the variation, they are still positively correlated with the components (Figure 8). The overlapping specimens (Figure 12, bottom [excluding 1704/400]) have leaves with an intermediate number of broadly lanceolate leaflets. None of these specimens were identified as hybrids, but given the morphological overlap observed in the wild (Delin et al. 2019) identification of clear hybrids would be difficult and possibly impractical.

Reproductive barriers

The collection of specimens included three identified as hybrids between *V. exaltata* and *V. sambucifolia* (Figure 13), that were originally collected in localities close to where most specimens of *V. sambucifolia* had been collected (Figure 9). One reason, however, that casts doubt on the hybrid status of these specimens is the difference in chromosome numbers between these taxa (Skalińska 1947). The development of reproductive barriers is expected to occur rapidly after the emergence of a polyploid lineage, which might be a reason why polyploid speciation has been a significant force in the evolution of angiosperms (Cruzan 2018b).

Based on previous research by plant taxonomists, Tod F. Stuessy recommended that phenetically similar, sympatric species should be delimited based on reproductive isolation. This

is because the biological species concept should take precedent over the morphological species concept, as reproductive isolation is the basis for phenetic differentiation (Stuessy 2009a). In this regard, whilst *V. sambucifolia* and *V. salina* appear to have little to no reproductive isolation (Delin et al. 2019), the difference in ploidy-level should provide a sufficient reproductive barrier to *V. officinalis* (Cruzan 2018b). Indeed, it is estimated that polyploidization through whole genome duplication (WGD) has occurred in 47% to 70% of all extant plant lineages, with angiosperms accounting for the highest density of WGD in the evolution of extant eukaryotes (Cruzan 2018a). Polyploid lineages appear to occur more frequently in plant communities that have experienced ecological disturbance where they probably have an advantage due to reduced vulnerability to inbreeding depression, which allows for higher degrees of self-fertilization (Cruzan 2018b).

In the European flora there are multiple examples of polyploid speciation due to human factors (Cruzan 2018b). Plants in the *V. officinalis* aggregate have probably been affected by such factors as well given their medicinal importance in pre-modern times (Christenhusz et al. 2017). This indicates that the emergence of polyploid lineages occurred recently in evolutionary terms. Evidence to support this assumption comes from the fact that polyploid populations in the aggregate show high intra-ploidy variation in genome size (Bressler 2017). Newly formed polyploid lineages have higher rates of genome reorganization, which in turn results in greater polymorphism (Cruzan 2018a). It stands to reason, therefore, that the general polymorphism observed in the aggregate (Titz et al. 1983) might reflect this rapid genome reorganization.

Evidence which might contradict the novelty of the polyploids is the inter-ploidy variation in genome size. It is a general pattern in the aggregate that the monoploid DNA content decreases as the chromosome numbers increase (Bressler 2017). This could be due to the process of diploidization, where selection for meiotic stability results in multiple deletions which improves bivalent pairing during meiosis (Cruzan 2018a). Also, plants with larger genomes tend to grow and diversify slower than plants with smaller genomes, lending further selective advantage to polyploids that have undergone diploidization (Cruzan 2018a). Besides genome size, another piece of contradicting evidence is that novel polyploids usually lack distinct phenotypes (Cruzan 2018b). Whilst the leaf morphology of *V. sambucifolia* and *V. salina* somewhat overlap with *V. officinalis* (= *V. exaltata*) (Figure 6), they can still be distinguished by specific traits: the stoloniferous habit of *V. sambucifolia*, and the coastal habitat of *V. salina* (Klingstedt 1933).

If polyploid lineages in the *V. officinalis* aggregate emerged recently, they would likely have undergone rapid evolution to produce these distinct traits. How all these polyploid lineages emerged is uncertain. Whilst hybridization seems like the obvious answer given its prevalence in the wild (Delin et al. 2019), there is research indicating that hybridization is of



Figure 14: specimens of *Valeriana sambucifolia* (likely subsp. *salina*) growing on rocky shoreline. Photographed by the author at Marholmen, Gothenburg.

secondary importance (Bressler 2017). If accurate, these results indicate that autopolyploidy has been more prevalent than allopolyploidy in the evolutionary history of the aggregate.

Autopolyploidy tends to result in populations of closely related species with few phenotypic distinctions (Cruzan 2018a), which is likely due to the fact that they originate in populations of plants that are all of the same species (Soltis et al. 2010). By comparison, allopolyploids have been easier to distinguish from parent species since they originate as hybrids (Soltis et al. 2010). A general lack of phenotypic distinction could explain the difficulty in delimiting *V. officinalis* from its close relatives, resulting in a taxon aggregate. Indeed, it is possible that the difficulty in identifying autopolyploids have led to underestimation of the total number of plant species (Soltis et al. 2010).

Limitations of the study:

Due to constraints on time and resources there are clear limitations to what conclusions can be drawn from the results. To begin with, no molecular data was used. It is important not to undervalue morphological and anatomical data, but there is a growing body of research which indicates that such data is at its most informative when used in combination with molecular phylogenetics and genotyping (Bersweden et al. 2021; Weststrand et al. 2016).

Whilst the sample size was large overall, not all taxa were equally well represented, with a large majority of specimens designated as *V. exaltata* and *V. sambucifolia*. All specimens were collected from southern Sweden, and the distribution of localities (Figure 9) might reflect collector bias to certain geographic regions. A study published in 2018 showed that research based on herbarium collections can indeed be affected by bias towards certain environments and plant groups (Daru 2018). It was also discovered that a majority of specimens in many collections were contributed by a limited number of collectors, raising the possibility that their own biases are reflected in the collections (Daru 2018). Our own study has probably been affected by this, as with the very limited information regarding the environments in which specimens were collected.

The research used for reference in this study seems to be primarily based on studies of plant communities in Central Europe and Sweden. Yet distribution maps of the aggregate show a broader native distribution across all of Europe and even West Asia (Kirschner et al. 2017+). This raises the question if valuable data has been left out due to geographical bias. A way to address this would be to investigate geographical centers of diversity. If such centers turn out to be primarily in Central Europe and Scandinavia it might justify the primacy of these regions in taxonomic and evolutionary research. It is likely that such centers are locations where species have existed for the longest period of time, making them possibly the center of origin for a species in question and its closest relatives (Singh 2021).

Data used for the analysis was entirely based on leaf morphology, which overlooks potentially important morphological and anatomical data from other parts of the plant body, seeds, and pollen. In a larger study, such data could either be analyzed separately, or potentially combined in a larger data set for a PCA or other statistical methods. PCA analyses in general have a few disadvantages to consider. The method is inherently reductivist as it sums up the variance in only two components. Considering that our analysis captured ca 90% of the variance, this might not be too concerning in our case. However, PCA does have a bias towards larger pairwise distances between data points. As a result, small pairwise distance between the extreme ends of the variance have a reduced weight on the component (Cheng 2022). These disadvantages will inevitably lead to the loss of information during the analysis and affects its reliability.

Conclusion

It is the opinion of the author that when making taxonomic decisions it is important to consider multiple lines of evidence. Taxonomy should inform about the evolutionary history of biological entities and should also allow for stable diagnosis of taxa. A multidisciplinary approach has



Figure 15: specimens of *Valeriana sambucifolia* (likely subsp. *salina*), showing vegetative morphology (left) and reproductive morphology (right). Photographed by the author at Marholmen, Gothenburg.

shown its usefulness in this regard in multiple studies (Bersweden et al. 2021; Weststrand et al. 2016), which is why any decisions made based on the results of this study would be premature at best. Instead, these results should be considered as possible directions for future research.

The biggest question we are left with concerns the possibility of resurrecting *Valeriana baltica*. Unfortunately, only ten specimens in total were available at Herbarium GB. Since nearly all were collected from, or grown from, plants found in the original locality, the designation of these specimens as *V. baltica* might reflect geographic bias. To conclusively resurrect *V. baltica* would require morphological data from a larger number of specimens and, if possible, from a wider geographic region. Given the widespread hybridization between plants of the same ploidy level in the taxon aggregate (Delin et al. 2019), and the identification of *V. baltica* hybrids (Table 2), there needs to be an investigation of the chromosome number and reproductive isolation of *V. baltica*.

Molecular data should therefore be derived from nuclear microsatellite loci, as these types of genetic elements are useful in investigating reproductive isolation in closely related plants (Bersweden et al. 2021). However, future research into *V. baltica* might be hampered by the taxon's possible extinction. Pleijel noted in the original description that the taxon is likely in decline (Lunds botaniska förening 1907). If its distribution was limited to a small region on the Baltic coast, development of such areas since 1907 could have resulted in the extinction (or near extinction) of *V. baltica*.

When it comes to the octoploids, our results do not give any reason to question the widely accepted interpretation of *Valeriana sambucifolia* as a distinct taxon, and of *Valeriana salina* as an infraspecific taxon (Hassler 2004 – 2023; Kirschner et al. 2017+; POWO 2022; SLU Artdatabanken 2022). In systematics, a “good species” is one that can be distinguished from close relatives by clear morphological discontinuity. The existence of specimens designated as hybrids between *V. sambucifolia* and *V. officinalis* (= *V. exaltata*) (Figure 13), does indicate that distinguishing the two taxa morphologically is not always straight-forward. But that does not

change the fact that the leaf morphology of *V. sambucifolia* appears to be generally distinguishable from closely related taxa (Figure 6) by the presence of larger and fewer leaflets (Figure 12, top right). This, along with the presence of stolons (Klingstedt 1933) and the reproductive barrier presented by polyploidy (Cruzan 2018b), does support recognizing *V. sambucifolia* as a “good species.”

Previous research has already given ample support for the recognition of *V. salina* as a taxon which is ecologically, and geographically distinct from *V. sambucifolia* (Klingstedt 1933; Lidberg et al. 2010; Mossberg et al. 2018). But the apparent lack of reproductive barriers or clear morphological discontinuity between *V. sambucifolia* and *V. salina* (Delin et al. 2019), might indicate that they represent syngameons. A common phenomenon in plants where closely related taxa are reproductively isolated from other taxa but not from each other, resulting in interbreeding clusters where taxa blend together. Delimiting such taxa as separate species is often considered artificial (Cruzan 2018b) and should probably be avoided. In contrast, it is recommended that infraspecific classification be implemented when populations with little to no morphological distinction show geographic/ecological differentiation (Stuessy 2009b).

An important consideration in taxonomy is to be careful with name changes and work to maintain stability as much as possible (Schuettpelez et al. 2018). Since our results do not give any significant reason to doubt the current consensus, we currently do not see any need to change the classification of Swedish octoploids in the *V. officinalis* aggregate into two infraspecific taxa: subsp. *sambucifolia*, and subsp. *salina* (SLU Artdatabanken 2022). Still, it should be considered to change the species name to the more widely accepted *V. excelsa*, since that name has priority (Holub 1996). The new names would then be *Valeriana excelsa* subsp. *sambucifolia*, and *Valeriana excelsa* subsp. *salina*. It might then be necessary to investigate the absence/presence of *V. excelsa* subsp. *excelsa* in the Swedish flora, as this taxon could have been overlooked in botanical research. Such efforts might still be justified so as to bring Swedish plant taxonomy closer to the more widely accepted framework, which would prevent the confusion of names in taxonomic research. Changes on a broader scale have been implemented before, including when Swedish plant taxonomy was changed in accordance with results from the Angiosperm Phylogeny Group (Mossberg et al. 2018).

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Appendix 1: Popular science summary

RESURRECTING THE DEAD? Systematics and Taxonomy of Swedish Valerians

Among the many flowering plants that have been used in ancient folk medicine, one of the most common in Europe is the common valerian (*Valeriana officinalis*). This species was first named by Carl Linneaus in 1753, making it one of the first plants in the world to receive a scientific name that consists of two latinized words: a genus name and species epithet. But the naming and classification of species is a scientific field unto itself: taxonomy. Much like how scientific hypotheses change, so to do the names of plant species.

Whilst the name *Valeriana officinalis* is still used, many plant populations previously assigned to this name have over the centuries been given their own names by various scholars. *Valeriana officinalis*, as traditionally delimited, is highly diverse in ecology, morphology, and genetics. Differing opinions on whether or not distinct populations should be considered as their own taxa (species or subspecies) have resulted in a “taxon aggregate” (a complex web of closely related taxa with multiple proposed names). In the SLU Artdatabanken, the main taxonomic resource in Sweden, two names are recognized as valid: *Valeriana officinalis* and *Valeriana sambucifolia*. The latter is in turn divided into two subspecies: subsp. *sambucifolia* and subsp. *salina*.

In my master’s project, I have put this taxonomic hypothesis to the test. Due to constraints in time and resources, I was only able to perform a preliminary study by comparing leaf morphology. This choice was motivated by the fact that leaves have been used before to distinguish between various taxa in the aggregate, and to identify them in the wild. I used 86 dried specimens stored in the Gothenburg herbarium (Herbarium GB). Each specimen had been assigned to any of the three names listed above, in addition to a fourth name listed in SLU Artdatabanken: *Valeriana baltica*, currently considered synonymous with *Valeriana officinalis*. Since the leaves of plants belonging to the aggregate are typically divided into multiple leaflets, I measured the length and width of the leaflets using a simple ruler. The data was analyzed using the PCA method, a statistical tool which finds the best summary of the variance. Results from the PCA led me to an interesting conclusion:



Figure 16: herbarium specimens assigned to *Valeriana officinalis* (left) and *Valeriana baltica* (right). Note the difference in leaf morphology.

It might be necessary to resurrect *Valeriana baltica* as its own taxon!

Whilst specimens assigned to subsp. *sambucifolia* and subsp. *salina* showed significant overlap with each other in the PCA, specimens assigned to *V. baltica* showed very little overlap with any of the other specimens. Indeed, those specimens differed from the typical leaf morphology by having simple, undivided leaves. Though it would be premature to make any taxonomic decisions based on a preliminary study, it does point to the possibility that *Valeriana baltica* could be resurrected as a distinct taxon. However, it has been over 100 years since this name was published. In the time since, *Valeriana baltica* could have gone extinct. If so, it would serve as a reminder of the importance of taxonomic research. A species cannot be protected unless it has a name.

ÅTERUPPVÄCKA DE DÖDA? De svenska vänderötternas systematik & taxonomi

Bland de många blommande växter som har använts i forntida folkmedicin, en av de vanligaste i Europa är läkevänderoten (*Valeriana officinalis*). Denna art namngavs först av Carl von Linné år 1753, vilket gör den till en av de första växterna i världen som fick ett vetenskapligt namn bestående av två latiniserade ord: ett släktnamn och ett artepitet. Men namngivning och klassificering av arter är ett vetenskapligt område i sig: taxonomi. Så som vetenskapliga hypoteser förändras, förändras namnen på växtarter.

Medan namnet *Valeriana officinalis* fortfarande används, många växtpopulationer som tidigare tilldelats detta namn har genom århundradena fått sina egna namn av olika forskare. *Valeriana officinalis*, som traditionellt avgränsad, är mycket varierad i ekologi, morfologi och genetik. Olika åsikter om huruvida distinkta populationer bör betraktas som sin egen taxa (arter eller underarter) har resulterat i ett "taxon aggregat" (ett komplext nät av närbesläktade taxa med flera föreslagna namn). I SLU Artdatabanken, den viktigaste taxonomiska resursen i Sverige, erkänns två namn som giltiga: *Valeriana officinalis* och *Valeriana sambucifolia*. Den senare är i sin tur uppdelad i två underarter: subsp. *sambucifolia* och subsp. *salina*.

I mitt masterprojekt har jag satt denna taxonomiska hypotes på prov. På grund av begränsningar i tid och resurser kunde jag bara utföra en förstudie genom att jämföra bladmorfologi. Detta val motiverades av det faktum att blad har använts tidigare för att skilja mellan olika taxa i aggregatet, och för att identifiera dem i naturen. Jag använde 86 torkade exemplar lagrade i Göteborgs herbarium (Herbarium GB). Varje exemplar namngivits med något av de tre namnen ovan, och även ett fjärde namn listat i SLU Artdatabanken: *Valeriana baltica*, som för närvarande anses synonymt med *Valeriana officinalis*. Eftersom bladen av växter som tillhör aggregatet vanligtvis är uppdelade i flera småblad, mätte jag längden och bredden på småbladen med en enkel linjal. Data analyserades med PCA-metoden, ett statistiskt verktyg som hittar den bästa sammanfattningen av variansen. Resultatet från PCA ledde mig till en intressant slutsats:



Figur 1: herbarium exemplar namngivna som *Valeriana officinalis* (vänster) och *Valeriana baltica* (höger). Notera skillnaderna i bladmorfologi.

Det kan vara nödvändigt att återuppväcka *Valeriana baltica* som sitt eget taxon!

Medan exemplar namngivna som subsp. *sambucifolia* och subsp. *salina* visade signifikant överlappning med varandra i PCA, exemplar namngivna som *Valeriana baltica* visade mycket liten överlappning med något av de andra exemplaren. Faktum är att dessa exemplar skilde sig från den typiska bladmorfologin i deras enkla, odelade löv. Även om det skulle vara för tidigt att fatta några taxonomiska beslut baserat på en förstudie, pekar det på möjligheten att *Valeriana baltica* skulle kunna återuppväckas som ett distinkt taxon. Det har dock gått över 100 år sedan detta namn publicerades. Under tiden sedan kunde *Valeriana baltica* ha dött ut. Om så är fallet skulle det vara en påminnelse om vikten av taxonomisk forskning. En art kan inte skyddas om den inte har ett namn.