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Pulsatilla patens and *Pulsatilla pratensis* (Ranunculaceae) in Estonia: distribution and ecology

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Abstract. Despite the great changes in land use, the distribution of *Pulsatilla patens* and *P. pratensis* (Ranunculaceae) in Estonia, reconstructed using herbarium specimens and notes, was quite stable throughout the 20th century. Considering the data on the present sizes and habitat conditions of 29 *P. patens* and 34 *P. pratensis* populations, in our estimation, around a tenth of the territory of Estonia should, at the moment, be habitable for these species. Both species prefer well-lit locations, created by some disturbance such as fire, logging, etc. The temporal deterioration of habitats through overgrowing could be buffered to some extent by the long life span of adult plants. The main threatening factor is current logging practice, which causes severe contraction of populations.

Key words: *Pulsatilla patens*, *Pulsatilla pratensis*, distribution, population size, habitats, land use.

INTRODUCTION

Species success or failure in modern floras is mainly determined by land use (Hodgson, 1986). Estonian landscapes changed greatly during the 20th century. The area of forests increased almost three-fold (from 14% to 42%) and the area of agricultural land decreased almost two-fold (from 65% to 30%) throughout the century (Mander & Palang, 1994; Mander et al., 1994). A similar trend has been observed elsewhere in Europe (Mücher et al., 2000). The increasing fragmentation, polarization, and disturbance of Estonian landscapes have been due to the concentration of agricultural activities, land amelioration, and the oil-shale industry (Mander & Palang, 1999).

To evaluate the impact of changing land use patterns on plant species distribution, knowledge of the distribution of the species in the past is required. In

Switzerland, for example, the old regional floras and herbarium specimens proved to be effective tools in reconstructing former distributions (Klecak et al., 1997). In Estonia, the available floristic material about the 20th century is quite extensive (Kukk, 1999), including herbarium specimens, floristic studies, and notes, which makes the reconstruction of former distribution areas possible in several cases. Complementing distribution data with the data about species ecology provides an opportunity to interpret the changes, but also to predict possible developments in the future. Different phylogenies of species complicate making generalizations about the traits that determine their success or failure under certain conditions. When information on the evolution of the group of species under consideration is scarce, it could be enough to compare pairs of congeneric species (Eriksson & Jakobsson, 1998).

The present paper describes the ecology and distribution of two pasqueflower species, *Pulsatilla patens* and *P. pratensis* (Ranunculaceae), in Estonia. A decline in the abundance of both species has been observed in many European countries, and they are listed in several national lists of threatened plants. For instance, *P. patens* is classified in Finland, Latvia, and the St. Petersburg region as care demanding; in Lithuania, Poland, and Sweden, as vulnerable; and in the Mecklenburg-Vorpommern area, as extinct (Ingelög et al., 1993). *P. pratensis* is classified in Latvia as care demanding; in Norway and the Mecklenburg-Vorpommern area, as vulnerable; in the St. Petersburg region and Lithuania, as rare; in Schleswig-Holstein and the Kaliningrad region, as endangered (Ingelög et al., 1993; Anon., 1992). In Estonia, *P. patens* is listed in the Estonian Red Data Book as care demanding (Lilleleht, 1998). Law protects both species since 1995.

The aim of the present paper is (1) to characterize the distribution of *P. patens* and *P. pratensis* in Estonia during the 20th century, (2) to describe the ecology of the species, (3) to interpret the distribution patterns, using knowledge about the biology and ecology of the species, and (4) to discuss the potential threatening factors, in order to provide recommendations for nature conservation.

MATERIAL AND METHODS

Species

P. patens and *P. pratensis* are long-lived perennials with an upright, branching rhizome, which results in clump forming by older plants. Vegetative spreading occurs only by infrequent splitting of bigger clumps (Rysina, 1981; Wildeman & Steeves, 1982). Both species flower in spring (mid-April to end of May), *P. patens* about two weeks earlier. Seeds are dispersed from the end of June to the beginning of July. Although the species have traits of anemochores, dispersal distances remain short (for closely related *P. vulgaris*, rarely more than 20 cm; Wells & Barling, 1971). Given enough warmth and moisture, germination occurs in late summer; in unsuitable conditions it is delayed until next spring. Only a transient seed bank is formed.

P. patens sensu lato shows widespread circumpolar distribution, growing in Europe as well as in North America (Hulten & Fries, 1986). In Europe it (ssp. *patens*) is mainly confined to East Europe and reaches its northern limit of distribution at 66° latitude in the regions of Arkhangel′sk and Pechora in Russia (Jalas & Suominen, 1989). In several isolated localities, for example in Germany (Hegi, 1965−1974) and in Finland (Uotila, 1996), its populations are considered to be relicts. In Estonia the species is at its northwestern border of continuous distribution.

P. pratensis is a European endemic, growing in Eastern and Central Europe. The northernmost habitats are around 60° latitude in Norway, Sweden, Estonia, and the St. Petersburg region (Jalas & Suominen, 1989). All northernmost populations, except Estonian, are isolated from the area of continuous distribution, and should be regarded as relicts of previous more widespread distribution (e.g. Torvik et al., 1998).

Distribution data

Considering the amount and character of the available information, as well as the expected reaction time to major land use changes, we divided the distribution data into three periods. The first period, from the 19th century to 1920, is characterized by scarcity of information, due to the small number of investigators–collectors, and by the concentration of their activity around larger towns (Tallinn, Tartu). Therefore, distribution data from that period reflect the regions where amateur botanists worked, rather than the actual distribution of *Pulsatilla* species. The available information is based solely on herbarium specimens, mainly kept in the herbariums of the University of Tartu and the Institute of Zoology and Botany of the Estonian Agricultural University. The oldest herbarium specimen of *P. pratensis* is dated 1846 and that of *P. patens*, 1855.

The second period, 1921–70, was the most intensive period of botanical investigations in Estonia. Before World War II, many professional as well as amateur botanists conducted extensive fieldwork. The composition of distribution maps of rare plant species began in 1932, and the mapping of Estonian vegetation, in 1934. After the war, in the 1950s, this work intensified again. Extensive fieldwork was carried out to complete the vegetation map (Laasimer, 1965) and a nine-volume book on the Estonian flora (Eesti NSV Floora, 1953−1984). Many herbarium specimens as well as floristic notes are available from that period. The greatest changes in land use in the 20th century occurred during that period (Mander & Palang, 1999). In the 1920s, many small farmsteads were established according to the Land Reform Act of 1919, but at the end of the 1940s an opposite trend — the concentration of agriculture in the form of soviet collectivization – started. Drastic changes took place in agriculture as well as in forestry practice.

The latest period, starting from 1971, is characterized by the concentration of botanical investigations on local floristic studies or on particular taxonomic groups. Considering the changes that had occurred in land use, a survey of previous distribution data, and the establishment of the current status of several rare plant species was started in the 1970s. Since 1994, systematic monitoring of rare and protected species is part of the State Monitoring Programme of the Estonian Environment. Data on pasqueflowers are also accumulated within the framework of this programme. Special studies on *Pulsatilla* species were started in 1999. As the precision of locality determination for older data is not high ("near a village" etc.), distribution maps are provided on the basis of presence–absence in the UTM grid system, widely used as a basis of biogeographical maps (e.g. Kotiranta et al., 1998). Quadrats of 10 × 10 km within the 50 × 50 km quadrats are used.

Population size

As the older data are quite inconsistent, and due to problems connected with estimation (see below), population sizes are only given for populations visited by the authors between 1995 and 2001. There were 29 such populations for *P. patens* and 34 for *P. pratensis*, distributed all over Estonia (Appendix). Populations were regarded as separate when the distance between them was at least 1 km.

Establishment of current population sizes appeared to be associated with several difficulties. First, a group of leaf rosettes, a clump, need not always comprise one genetic individual, as several seeds may disperse and establish together. As the excavation of plants or their DNA analysis are the only ways to verify this, we refer hereafter not to individuals, but to plants or clumps. Secondly, population size is not estimable on the basis of flowering plants, because only a fraction of plants flower in any one particular year. The leaves generally develop later, after flowering, and so nonflowering individuals remain unnoticed. For instance, on a 10 × 10 m monitoring plot for *P. patens* (Vastseliina, South Estonia) there were 18 plants, 9 of them generative, on 5 May 1999. On 8 June we counted 164 plants already, although the number of flowered plants had not changed. Population size estimation based on clumps of leaves is also difficult, especially for *P. pratensis*, whose bipinnate leaves are quite unremarkable in vegetation. So, although the above-mentioned problems are considered, the established population sizes still remain only very rough estimates and are given in orders of magnitude 10, 100, 1000, and 10 000.

Habitat

Habitat data were compiled for the same set of recently visited populations as the population size data (Appendix). Forest habitats were classified into site types according to Lõhmus (1984), and the site type groups are based on the hierarchical classification scheme by Paal (1997). In the case of other vegetation types, Paal (1997) was followed. One population could inhabit locations belonging to different site types.

Light availability was estimated visually, dividing the habitats into open, half-open, or closed (Appendix). This corresponds to no shade, partial shade, or total shade in the case of trees and bushes.

Data on soil conditions were collected from eight sites all over Estonia where one or both species occur. Soil types were estimated on the basis of soil profiles, using the classification by Reintam (1986). Because of the varying terminology of soil classification, only the main types (rendzina, podzol etc.) are mentioned here. Roots of *Pulsatilla* species are mainly distributed in the upper 30 cm layer of soil (cf. also Rysina, 1981), but occasionally they can reach at least twice as deep (M. Öpik & I. Pilt, pers. comm.). Soil samples were taken so that they contained a mix of upper 30 cm horizons (without O or (O) A horizon). The values of pH and nitrogen, phosphorous, and potassium content are means of samples taken from one profile per site. Also the humus content was analysed. Processing of samples followed Moore & Chapman (1986). The soil pH was determined with a pH meter in a soil–water mixture (ratio 1:2.5). For the determination of nitrogen content the soil sample was digested with H_2SO_4 to convert organic N to NH_4, which was distilled after alkalization and detected by titrimetry. The total soil organic matter was estimated by measuring the content of organic carbon. The method described is a wet-oxidation procedure using potassium dichromate with external heat and back titration to measure the amount of unreacted dichromate. Mobile forms of phosphorus and potassium were determined by the Egner–Riem–Domingo method.

RESULTS

Distribution

Two main regions of distribution could be distinguished for *P. patens*: East and Southeast Estonia, and North and Northwest Estonia (Fig. 1). This species is completely absent on the islands and has a very scattered distribution in West and Northeast Estonia. It disappeared from the surroundings of larger towns (Tallinn, Tartu) and from central Estonia already at the beginning of the 20th century – it has not been found from 14 UTM quadrats since 1920. During the period from 1921 to 1970, *P. patens* occurred in 42 quadrats, and from 1971 to 2000, in 39 quadrats. Only 18 quadrats were occupied in both these periods. In general, the appearances–disappearances occur within neighbouring quadrats. However, it seems to us that this can be explained by different fieldwork description rather than seed dispersal. The earlier data are often nondescript, and there could be dislocations on the borders of two neighbouring UTM quadrats, especially in the case of localities on the edge of quadrats. No clear retreat or expansion on a regional scale is observable.

The distribution of *P. pratensis* covers the regions where *P. patens* is found, but it is also frequent throughout the whole of North Estonia, including the northern islands, and in West Estonia and the western islands (Fig. 1). Since 1920 *P. pratensis* has not been found in eight UTM quadrats that it previously inhabited. Of the 85 quadrats occupied from 1921 to 1970, according to our data only 37 were still occupied after 1971. Thus, of the 72 quadrats occupied during

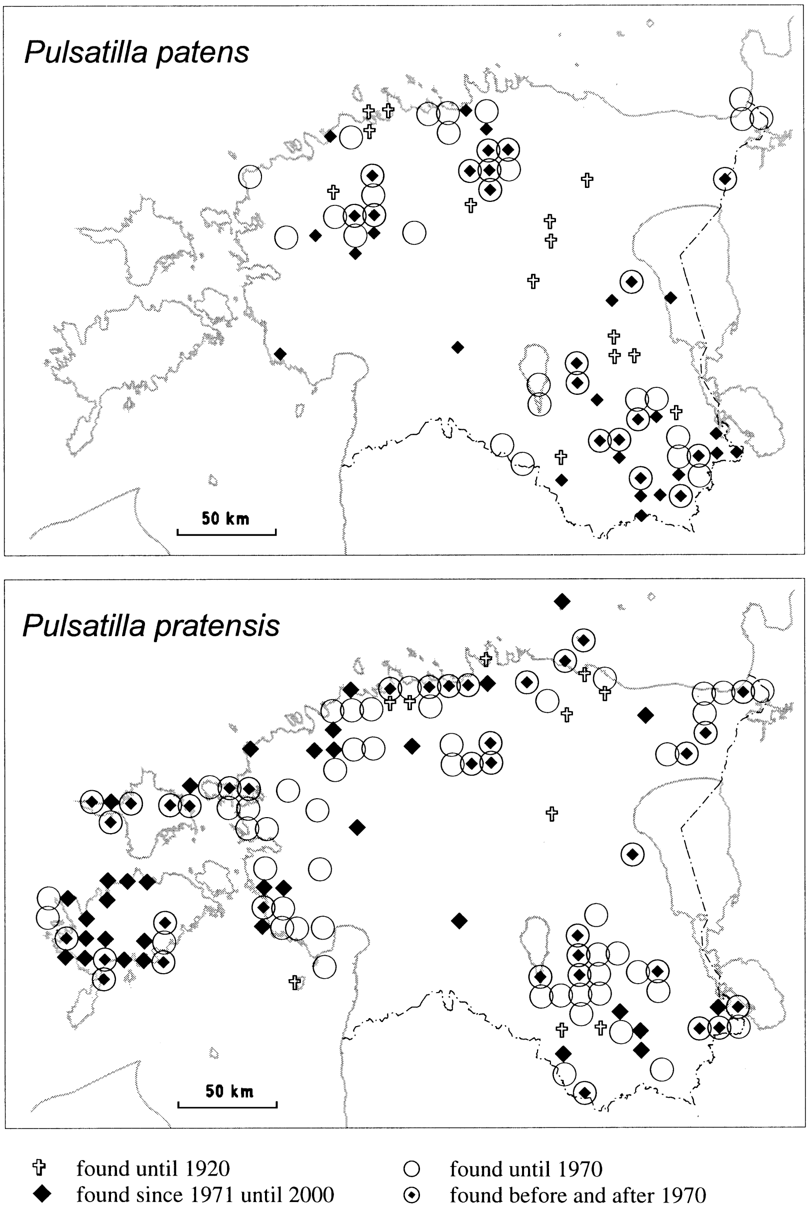

Fig. 1. Distribution of *Pulsatilla patens* and *P. pratensis* in Estonia.

the period from 1971 to 2000, 35 (almost 50%) are “new sites”. The same phenomenon is observable in the case of *P. pratensis*. Still, when comparing the last two periods, retreat on the Estonian mainland and expansion on Saaremaa Island can be observed.

Population size

The (local) population sizes of both species were very variable (Appendix). Of the 29 populations of *P. patens*, 5 were of an order of magnitude (OM) of 10 000 plants, 5 of OM of 1000, 13 of OM of 100, and 6 of OM of 10 plants. Of the 34 populations of *P. pratensis*, the corresponding numbers were 8, 12, 12, and 2. So, in general, populations are larger in the case of *P. pratensis* – almost 2/3 of the populations, compared to 1/3 for *P. patens*, are of a size of a thousand plants or more. In some places, like the western coast and islands, *P. pratensis* is distributed almost continuously over several kilometres.

Habitat

In Estonia, both *P. patens* and *P. pratensis* grow in various habitats, and their habitat preferences are at least to some extent overlapping, since there are several mixed populations (Appendix). The majority of populations of both species (21 of 29 for *P. patens*, 20 of 34 for *P. pratensis*) are found in pine (*Pinus sylvestris*) dominated boreal heath forests of *Cladina* or *Calluna* site type and in dry boreal forests of *Vaccinium vitis-idaea* site type, occasionally also in more humid *Vaccinium myrtillus* site type. Of alvar areas, *P. patens* is found more often in sparse forests of *Arctostaphylos*–alvar and *Calamagrostis*–alvar site types. *P. pratensis* prefers the more open areas of dry alvar grassland site type and dry boreal grasslands, and is abundant in coastal areas of grey dyne site type as well. Both species also grow in open anthropogenic habitats such as road and railroad edges, which are mown or burned. In other habitats too, human influence is frequently evident, including logging, grazing, excavations for sand, etc.

Pasqueflowers usually grow in open or half-open locations such as forest edges, clearings, and slopes of southern exposition, where the shrub layer is sparse, the herb layer is low, and graminoids are scarce or scattered. While populations or parts of populations of *P. pratensis* were found growing in open (16 sites) and half-open locations (20 sites) with similar frequency, then *P. patens* was considerably more frequent in half-open locations (23 sites) than in open ones (7 sites). Under closed canopy, *P. patens* was found in seven and *P. pratensis* in six locations.

Soil conditions

In various habitat types where the species grow, the substrates also vary. All main types of dry soils (soils without signs of gleization) in Estonia are represented (Reintam, 1995), including rendzinas, podzols, brown forest soils, and even sands and gravels in the coastal epilittoral zone (Table 1). The soils have a variable pH, ranging from 5.1 to 8.4 for *P. patens*, and from 5.4 to 8.9 for *P. pratensis*. The soil nitrogen content varied considerably for both species, being as low as 0.01 and as high as 1.34%, as did movable phosphorus (from 0.6 to

Table 1. Soil properties of *Pulsatilla patens* (pat) or *P. pratensis* (prat) sites. Samples collected in 1999 and 2000. pH (H_2O), N (overall %), P (mg/100g soil), and K (mg/100g soil) content in the upper 30 cm layer of the soil. Humus content of the (O) A horizon. See Appendix for population and habitat data

Site: soil type; thickness of organic horizons (cm); texture	Species	Year	pH	N	P	K	Humus
Apuparra: podzol; O 2–4, A 0–2; clay–sand	Pat	2000	5.1	0.086	9.4	4.0	7.06
Gorodenko: brown forest soil; O 2–5, A ~20; sand–clay	Pat	2000	5.7	0.077	4.3	3.5	3.26
Lipstu: thin rendzina; A ~5 cm over massive limestone	Pat	2000	6.8	1.342	0.6	27.4	31.14
Piusa: podzol; (O) A < 3; clay–sand	Pat/pra	1999	8.4	0.050	1.7	6.6	–
Soomaa: podzol; O 1–2, A 10–15; clay–sand	Pat/pra	1999/ 2000	7.7/ 5.4	0.059/ 0.033	10.1/ 6.1	5.4/ 3.1	–/ 2.14
Pangodi: podzol; O 1–4, A 0–3; clay–sand	Pra	1999	8.6	0.109	9.8	13.3	–
Ramsi: coastal gravel covered with sand (10–70); (O) A 0–3	Pra	2000	8.9	0.010	1.3	2.1	–
Varbla: podzol; O ~5, A 1–3; clay–sand	Pra	1999	7.2	0.057	4.1	6.1	–

– Not determined.

10.1 mg P/mg soil) and potassium (27.4 to 2.1 mg K/mg soil). The high humus content measured in Apuparra (7.06%) is attributable to earlier fires in the area. Rendzinas are characterized by an extremely high humus content (26.5±5%; Zobel, 1985) reflected also in the Lipstu site (31.14%).

DISCUSSION

Despite the changes in the course of time, the overall distribution pattern for both *Pulsatilla* species, especially for *P. patens*, in Estonia remained more or less the same during the 20th century. Comparison of the distribution before and after 1970 shows that appearances and disappearances involved mainly neighbouring UTM quadrats. The "regionally static nature" of *Pulsatilla* species is well known. In Finland *P. patens* grows only in the region of South Häme, where it has existed since the last glaciation (Uotila, 1969, 1996). In England a closely related species

– *P. vulgaris* – has appeared to be unable to colonize areas with abiotic conditions similar to those in its current habitats (Wells & Barling, 1971).

Since the first half of the 20th century, the main agricultural activities have shifted from western to eastern Estonia (Mander & Palang, 1999). Decline of *P. pratensis* on the Estonian mainland and its expansion on Saaremaa Island is probably associated with this change. While at the beginning of the 20th century 88% of the area of Saaremaa Island was in agricultural use, then in 1992 this proportion was only around 30% (Mander & Palang, 1999). However, the overgrowing of former open areas, remaining after the cessation of economic activities, is under way. The area of alvar grassland, which is characteristic of western islands and West Estonia as a whole, is rapidly decreasing. When two decades ago the area of alvar grassland was estimated at 16 000 ha (Aug & Kokk, 1983), then today it has declined considerably, making up only a third of this figure (Pärtel et al., 1999). Areas with permanently dry soil constitute about 3000 to 4000 ha at present (M. Pärtel, pers. comm.).

The buffering capacity of a species against changing environmental conditions involves efficient dispersal, both in space and time. For many temperate forest and grassland species, long individual life span is the trait enabling its spreading in time, since these species usually lack a persistent seed bank (Thompson et al., 1997; Baskin & Baskin, 1998). Life span is also the main determinant of the speed of reaction to altering conditions – long-lived species react considerably slower (Eriksson, 1996).

Several current localities, especially for *P. patens*, consist of only a few plants in locations where the conditions could be assumed to have been more favourable a decade or two ago. Therefore, many "new" populations are quite likely "old" ones that have remained unnoticed in previous surveys, since their numbers had been severely reduced by unfavourable conditions. For the same reason we could assume that several "extinctions" are due to the use of inexact locality information when checking the old data, due to visiting the places at an unsuitable time (when leaves are not developed, or when the vegetation is already too dense for a population to be noticed), etc. When the populations have passed several severe bottlenecks, this should also be revealed in population genetic structure (Ellstrand & Ellam, 1993); however, we have no data about this at the moment.

Vigorous populations are found in open or half-open locations with good light availability. An improvement of light conditions usually takes place as a result of some disturbance, such as fire, which removes the ground vegetation, but leaves rhizomes of pasqueflowers almost undamaged (Wildeman & Steeves, 1982; Uotila, 1996). Available statistics about forest fires in Estonia dates back to 1921. The total area affected annually has been very variable, from 10.9 ha in 1977 to 4733 ha in 1933 (Alton, 2000), the latter constituting about 0.6% of the total forest area of that time (forest area according to Mander & Palang, 1999). Considering that most fires occur in dry areas, preferred by pasqueflowers (suitable forest site types constitute around 14% of Estonia's total forest area, according to Lõhmus, 1984), their impact could still be significant. Fires remove the moss layer. Vegetation descriptions made with an interval of 5 years (Karijärve, East Estonia) showed that the populations of both species, but especially of *P. patens*, had diminished substantially. The only reason for this seems to be an increase in moss layer density.

Other disturbances of anthropogenic nature besides fires, such as logging, mowing, grazing, etc., also facilitate regeneration by seeds, which could be very unreliable in natural established vegetation. As the two *Pulsatilla* species have no persistent seed bank, regeneration depends not only on suitable conditions for establishment, but also on seed production at any particular locality at any moment of time. Widen & Lindell (1995) reported great annual variation in seed production for *P. pratensis*. As seeds of both species usually disperse over short distances, establishment of new local populations or expansion of the existing ones is evidently dispersal-limited. The species are hence quite disturbance-dependent, and they should therefore be classified as apophytes (Enari, 1944; Uotila, 1969, 1996), rather than hemeradiophores (Kukk, 1999).

In respect of soil nutrient status and pH, both species show a rather wide amplitude of tolerance. In general, *P. pratensis* seems to prefer sites with more neutral soils (cf. also Ellenberg et al., 1991). Higher pH values are mainly attributable to limestone content in the soil profile, but in coastal zones (see Ramsi site in Table 1) also to the influence of seawater, which has a pH around 9 (Reeve & Barnes, 1994).

In respect of moisture availability, *P. patens* has a narrower amplitude of tolerance (Uotila, 1969) and prefers more humid sites (cf. also Ellenberg et al., 1991) than *P. pratensis*. An adverse impact of low moisture availability was observed (I. Pilt & M. Öpik, pers. comm.) in a mixed population (railroad edge near Piusa, South Estonia) that suffered from severe drought in late summer 1999. Leaves of *P. patens* withered totally; those of *P. pratensis* showed strong signs of drought stress, but mostly survived.

On the basis of the distribution of the site types where soil conditions are suitable for *Pulsatilla* species, we estimated that around 10% of the territory of Estonia should be potentially habitable for both species. These potentially suitable habitats may become even more favourable, as mentioned above, when appropriate light conditions are provided. There are several threatening factors that may cause extremely severe population reduction and/or eliminate regeneration possibilities in the close proximity of established plants. Decreases in the distribution are probably caused by fragmentation of habitats and by peculiarities in reproductive systems of plants (Kull et al., 2002). Forest clear-cutting, whose volume has greatly increased in Estonia during the last years, is definitely the main factor destroying the habitats of the *Pulsatilla* species. Despite the fact that cutting improves lighting, the current practice of clear-cutting has many adverse impacts on the pasqueflowers. Heavy machines destroy rhizomes, and soil disturbance promotes the invasion of ruderal species or light-demanding grasses, forming a dense vegetation cover, under which the establishment of new *Pulsatilla* seedlings is impossible. Frequently logging debris, windfallen trees, etc. are left on logging sites. This can promote species biodiversity (fungi, mosses, etc.), but also results in the eutrofication of the site and the following establishment of a dense vegetation cover. Overgrowing of formerly open grassland areas is also harmful to pasqueflowers, especially *P. pratensis*.

Destruction of habitats and established populations due to the expansion of human settlement does not endanger the present-day populations of *P. patens*, as this species has already disappeared from the vicinity of towns. *P. pratensis*, on the other hand, is frequently also found in forest-park suburbs. Although *P. patens* is protected by the law, its eye-catching flowers are often picked. The influence of this as a threatening factor may still be quite low. Protection efforts must therefore concentrate on the avoidance of overgrowing, as well as the adoption of sustainable logging practices in the species' current habitats.

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APPENDIX

HABITAT DATA ABOUT *P. PATENS* AND *P. PRATENSIS* POPULATIONS IN ESTONIA, CHECKED 1995–2000

Region denotes the placement of a population, based on the UTM grid system, and is referred to by two letter symbols (Fig. 2). Mixed populations are marked with an asterisk.

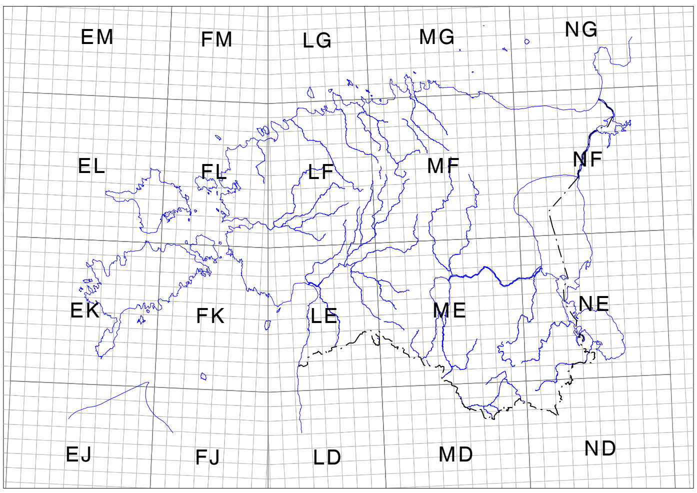

Fig. 2. UTM grid notation.

Pulsatilla patens

Population	Region	Pop. size	Light	Growth site type group/site type
Abru	LF	10 000	Half-open/open	Alvar forests and shrublands/*Arctostaphylos*-alvar
Apuparra	MF	1 000	Half-open/closed	Boreal heath forest/*Calluna*
Elva	ME	100	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Gorodenko	NF	1 000	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Harakajärve	MF	10 000	Half-open/closed/open	Boreal heath forest/*Calluna*
Hummuli	ME	10	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Jussi lakes	MF	100	Half-open	Boreal heath forest/*Calluna*
Kaiu	MF	10	Closed	Boreal heath forest/*Cladina*
Karijärve*	ME	10	Half-open	Dry boreal forest/*Vaccinium myrtillus*
Koonukõrve	MF	100	Open	Dry boreal heath grassland
Lindora	NE	10	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Lipstu	LF	10 000	Half-open/open	Alvar forests and shrublands/*Arctostaphylos*-alvar
Mustametsa	ME	10	Closed	Dry boreal forest/*Vaccinium vitis-idaea*
Osula*	ME	100	Half-open	Yard
Palojärve	ME	1 000	Half-open	Road edge
Piusa*	NE	10 000	Open	Railroad edge
Punamäe	MF	100	Closed/half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Rootsiküla	NE	10	Open	Boreal heath forest/*Calluna*
Rutka	MF	100	Half-open	Alvar forests and shrublands/*Calamagrostis*-alvar
Soomaa*	ME	100	Half-open	Boreal heath forest/*Calluna*
Türisalu	LF	100	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Umbsaare	NE	100	Closed/half-open	Boreal heath forest/*Calluna*
Vana-Nursi	ME	10 000	Half-open/open	Boreal heath forest/*Calluna*
Vargamäe Hills	MF	100	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Vastseliina	NE	1 000	Half-open/closed	Dry boreal forest/*Vaccinium vitis-idaea*
Verijärv	NE	100	Half-open	Dry boreal forest/*Vaccinium myrtillus*
Veski	NE	100	Half-open	Boreal heath forest/*Calluna*
Vulbi	MF	1 000	Half-open	Alvar forests and shrublands/*Calamagrostis*-alvar
Värska*	NE	100	Half-open	Boreal heath forest/*Calluna*, *Cladina*

Pulsatilla pratensis

Population	Region	Pop. size	Light	Growth site type group/site type
Andineeme	MF	1 000	Half-open	Boreal heath forest/*Calluna*
Andineeme–Muuksi	MF	1 000	Closed	Dry boreal forest/*Vaccinium vitis-idaea*
Asema	ME	1 000	Open	Dry boreal forest/*Vaccinium vitis-idaea*
Einby	FL	1 000	Half-open/closed	Road edge

Population	Region	Pop. size	Light	Growth site type group/site type
Ennu, Vätta	EK	1 000	Open	Dry alvar grassland
Harilaid	EK	10 000	Open	Dry alvar grassland
Jõuga	NF	100	Open	Dry boreal grassland
Järve	EK	100	Open	Gray dyne site type
Kaberla	MF	100	Half-open/closed	Dry boreal forest/*Vaccinium vitis-idaea*
Karepa	MG	10 000	Half-open	Boreal heath forest/*Calluna*; gray dyne site type
Karijärve*	ME	1 000	Half-open	Dry boreal forest/*Vaccinium myrtillus*
Kutniku	MF	100	Half-open/closed	Dry boreal forest/*Vaccinium vitis-idaea*
Kärgula	ME	100	Open	Old opencast
Matsirand	FK	1 000	Half-open	Boreal heath forest/*Calluna*
Mustametsa	MF	100	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Mäepea	EK	100	Open	*Arctostaphylos*-alvar
Narva-Jõesuu	NF	100	Half-open	Boreal heath forest/*Calluna*; gray dyne site type
Osula*	ME	10 000	Open/half-open	Yard
Palumäe	ME	10 000	Open/half-open	Inland sandy plain site type; dry boreal forest/*Vaccinium vitis-idaea*
Piusa*	NE	10 000	Open	Railroad edge
Pudisoo-Kolga	MF	100	Closed	Dry boreal forest/*Vaccinium vitis-idaea*
Ramsi	FL	10 000	Open	Gray dyne site type
Riisipere	LF	10 000	Half-open/closed	Dry boreal forest/*Vaccinium vitis-idaea*
Ristna	EL	1 000	Half-open	Boreal heath forest/*Calluna*
Soomaa*	ME	1 000	Half-open	Boreal heath forest/*Calluna*
Suur Umbjärv	ME	1 000	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Tammiku	LF	100	Half-open	Alvar forests and shrublands/*Calamagrostis*-alvar
Vaindloo, Uhtju	MG	100	Open	Dry boreal grassland
Varbla	FK	1 000	Open/half-open	Boreal heath forest/*Calluna*
Varesmetsa I	NF	100	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Varesmetsa II	NF	10	Half-open	Dry boreal forest/*Vaccinium vitis-idaea*
Vasalemma	LF	10	Open	Dry alvar grassland
Vatla	FK	10 000	Open	Dry alvar grassland
Värska*	NE	1 000	Open/half-open	Boreal heath forest/*Cladina*

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Pulsatilla patens ja *Pulsatilla pratensis* Eestis: levik ja ökoloogia

Indrek Pilt ja Ülle Kukk

Palu-karukella (*Pulsatilla patens*) ja aas-karukella (*Pulsatilla pratensis*) levik Eestis on 20. sajandi jooksul olnud küllaltki stabiilne, hoolimata suurtest maakasutuse muutustest. 29 palu-karukella ja 34 aas-karukella populatsiooni ning nende kasvukohtade analüüsi alusel võiks ligikaudu kümnendik Eesti territooriumist sobida nimetatud liikide kasvuks. Mõlemad liigid eelistavad valgusrikkaid kasvukohti ja on soodustatud mõningasest inimtegevuse mõjust, nagu põlengud, metsaraie vms. Taimede pikk eluiga pärsib teataval määral kasvukohtade kinnikasvamise halvendavat mõju. Suurim ohuallikas karukellade populatsioonidele on praegusel ajal kasutatav metsaraie viis, mille tõttu moodustub tihe rohttaimkate ja halvenevad valgustingimused.