Environmental changes related dynamics of the number of sites of rare indigenous and exotic plant species in Latvia

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Inventory data on the sites of rare plants (4,456 sites) and a follow up of the advent and naturalization of exotic species in the Latvia's flora over the last two centuries are used to analyse the dynamics of environmental changes. The analysis of detecting sites of rare species and the naturalization dynamics of exotic species shows that the species preferring slightly acid or neutral substrates tend to increase, whereas those preferring acid oligotropic substrates remain constant or tend to decrease (estimates made by using the Ellenberg's scales). The range of occurrence is increasing mainly for the representative species of evergreen deciduous forests (*Querco-Fagetea*) and the subcontinental herbaceous communities (*Festuco-Brometea*). Environment eutrophications (climate warming, moderate pollution by nitrogen containing components) thus under way in Latvia results in a gradual increase in summergreen forest biome and decrease in that of boreal conifers in Latvia and, possibly, all over the Eastern Baltic.

Key words: rare plant species, exotic plant species, site, plant communities, environment, eutrophication.

Introduction

In studies of environmental changes, indicator plants, often pertaining to indigenous as well as the exotic species that have naturalized into the local flora, are used as evidences of changes under way. The relationship between these plants, their occurrence and affinity to definite biotopes reflect the existing tendencies in florogenesis and the overall environmental changes in the given region.

A narrow ecological range and restricted life room is typical of rare plant species. Normally they are found as small populations with some specific biotopes and plant communities. Therefore, in contrast to the common and widespread species, they are more sensitive to environmental changes. Variations with time in the number of sites where the rare species are found or the same for the sites detected as new is a simple indicator of changes in the occurence of rare plant species. Undoubtedly, the number of newly detected (or new) sites of rare plants also reflect the level of the activity of botanists and other researchers dealing with environmental studies. The more intensive and scrupulous is the survey of the area under study, the higher are the chances to detect new sites. In this respect the number of new sites of rare plants recorded over a definite period of time is a valuable source of information for historical botany. However, the above mentioned data contain also information of another nature: the number of newly recorded sites over a period of time may be said to reflect the variations in the occurrence of rare (and also endangered) plant species and the status of the corresponding populations. For the most part, the rare species go with definite, most commonly rare plant communities which serve as a sensitive indicator of the status of the environment and corresponding biotopes. In case the number of sites comprising definite species is increasing, the growing (environment) conditions are favourable for it, and, vice versa, if there is no increase, or a decrease in the number of sites, the given species has a restricted life room (rare biotope), or the growing conditions for it are impaired.

Besides, the naturalization of exotic plant species also reflects the changes in the environment. The more intensive the synanthropication (appearance of exotic plant species in the region's flora), the more pronounced the environmental changes.

The naturalization intensity of exotic plant species and the range of their occurrence indicate the availability of favourable for them ecological environment/ biotopes.

The tasks of the given study were the following:

• to appreciate, over the period of time between 1777 and 1980, the variations in the number of sites where rare plant species are found;

• to analyse the naturalization intensity of exotic plant species over the last 200 years;

• to elucidate environmental changes related dynamics in the number of sites of marginally rare indigenous plant species and the naturalization of exotic species.

Data analysed

In order to investigate the dynamics in detecting the sites of rare plant species, use is made of the inventory data obtained by I. Fatare (Фатаре, 1978; 1980; 1981; 1986) for the protected sites of rare plant species and those the protection of which is anticipated. The overall area covered by the inventory is 71 km^2 (7.7X9.3 km). With the aid of the data on 168 species (4,456 sites) in the above inventory, quantity series on a decade basis for new sites detected over the period between 1777 and 1980 were built up. The sites referred to the sources in the 18th c. (Hupel, 1777; Fisher, 1778; 1784) are all included in one period - sites found until the year 1800. To analyse the naturalization of exotic species (neophytes, ergasigophygophytes, ephemerophytes), use is made of the most important literature sources on the Latvia's flora of the 18-20th centuries, stating the year in which the given species is first mentioned. In a similar way, on a decade basis and starting with the year 1800, drawn up is the quantity series for the exotic plant species naturalized. Electronic tables EXCEL 5.0 are used to analyse the time series for the sites detected.

Variations in the Number of Sites of Rare Indigenous Plant Species

Over the last 200 years the recorded number of sites of rare indigenous species varies over a very wide range (Fig. 1). The period of time considered in the study may be divided into two subperiods: one, between 1777 and 1891, the other, between 1891 and 1980. As to the first subperiod (18th – 19th centuries), only 307 sites are

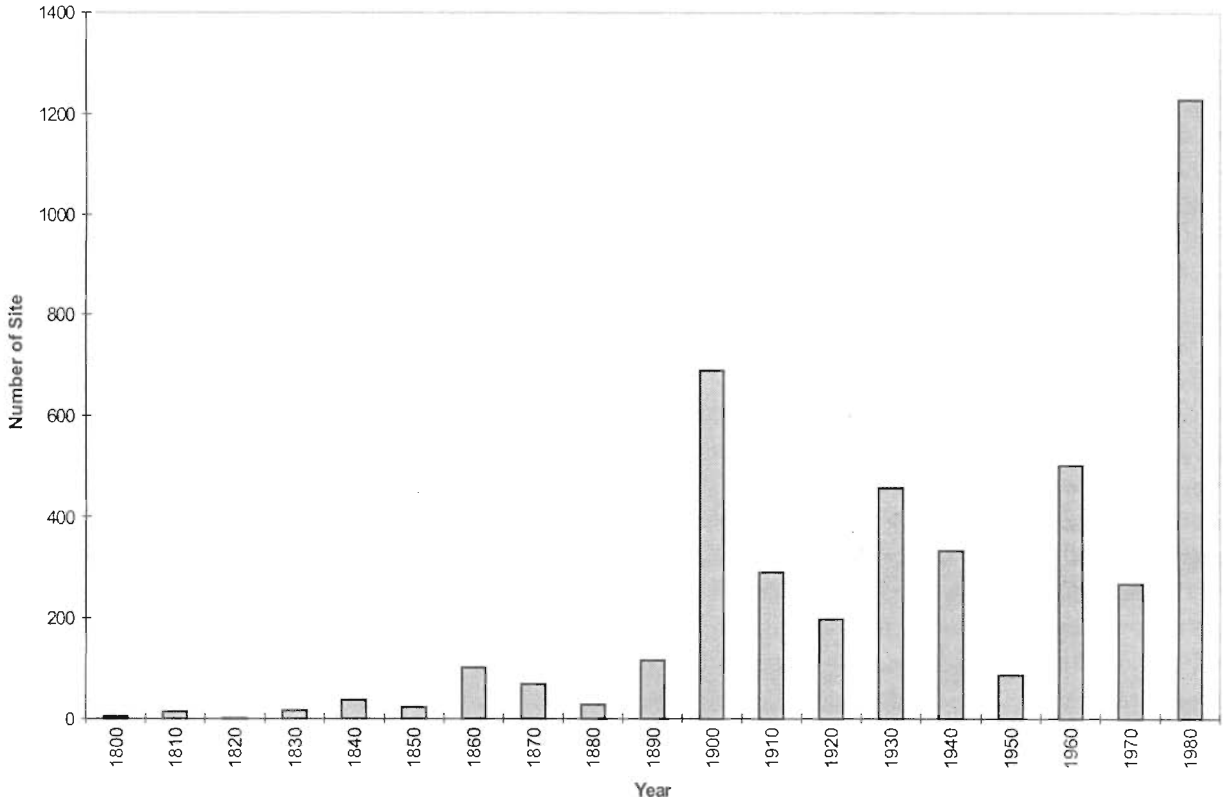

Fig. 1. The dynamics of detecting new sites of rare plant species

mentioned in the literature (7% of the total number of records analysed). For the second subperiod (the end of the 19th c. and the 20th c.), the number of sites recorded in the literature is 4,149. The mentioned subperiod is distinquished by a great number of sites recorded and wide variation in these records in individual decades. As to the number of sites recorded as new, the latter period may be divided into three spans:

• the 1970s, with the highest number of sites recorded as new – 1,229 (28%). This period is typical of floral research at the local level, whereby the data on the sites containing rare plant species were summed up as well as the biology and ecology of rare species (*Taxus baccata, Myrica gale*) studied.

• the last decade of the previous century (1891-1900) when 689 new sites (16%) were recorded. This is the period when F. Lehmann's (Lehmann, 1895; 1896) summarizing monograph on the flora of the region of Vidzeme (North-East of Latvia) was published and the activities by K. Kupfer for studying the flora of the Baltic provinces of Russia were started.

• the decade between 1951 and 1960 when 501 (11%) site of rare plant species was inventoried. During this period the first geobotanical map of Latvia was drawn up and the field studies on different areas of Latvia were intensive. However, the activities in the 1920s and 1930s are rather intensive, too: new recordings of sites having rare plant species, which number 457 and 333, respectively. Thus, the data show the level of activity of the Latvian botanists in different periods of time.

On a per-species basis, the number of the new sites of rare plants recorded shows an uneven variation over the period considered, for some higher, for some lower. For this reason, the dynamics of the sites detected is believed to reflect also the variations in the occurrence of a particular species. To establish the variations in the occurrence of rare species over the last 100 years, compared, on a per-species basis, is the number of sites recorded for two 30-year periods, one between 1891 and 1920, the other between 1951 and 1980. When comparing the number of sites recorded for each particular species between the two periods, we may distinguish between three groups of species: Group 1 – the number of sites recorded as new has increased, i.e. the species is advancing; Group 2 – the number of sites containing the particular species and recorded as new is decreasing or no sites have been found, i. e. the species is receding; Group 3 – the number of sites recorded is constant.

During the 20th c. the number of sites recorded as new has increased for 91 species. The highest increase in the number of sites is for *Aquilegia vulgaris* - 126, this increase is above 50 for three species - *Dactulorhiza baltica*, *Malus sylvestris* and *Nymphaea candida*, with this figure exceeding 10 for 28 more species (Table 1). For a considerable number of species (36) the number of sites detected as new varies between 1 and 3. An increase so insignificant cannot be regarded as sufficient for evaluating the occurrence of the species.

Over a period of time considered, the number of sites recorded as new has decreased for 58 species. The most considerable decrease is noted for *Isoetes lacustris* – 19 sites, for 5 more species this decrease exceeds 10 sites, for 14 species – above 5 (Table 2), whereas for 38 rare species the reduction of the number of sites is insignificant (a few sites only). For 18 species the number of sites recorded has remained the same.

As to the rare indigenous species, over the 20th c. the number of sites recorded as new has increased for more than a half of them (54%) while it has decreased for one third of species (35%). The species showing an increase in the number of sites, for 32 (19%) of them it is above 10; as to the species tending to decrease, for 20 species the reduction of the number of sites exceeds 5. The latter is believed to be informative enough for elucidating environmental changes.

The Rare Plants – Indicators of Environmental Changes

The number of the sites of rare plants and changes in it depend on the status of the corresponding biotopes they belong to as well as on different factors, both increasing or decreasing, impacting the environment (Ellenberg, jun., 1983). That is why it is possible and also important to identify the environmental factors whereby the occurrence of rare species tends to increase, remains constant, or tends to decrease. For this purpose, the values of environmental factor (by using Ellenberg's scales) are estimated and the rare species/plant community relationship established, including the specific range of occurrence for the particular species showing both an increase in the number of sites over the last century by 10 and above and a decrease by 5 sites and above. All these are marginal species. When comparing the environmental factor values for two groups of rare species, there is a significant difference between the two environmental factors – soil reaction and the nitrogen content in the substrate. The advancing species are predominantely found on the sites having a slightly acid

Table 1. Species showing an increase in the number of sites recorded as new

Species	The number of sites (1891-1920)	The number of sites (1951-1980)	Increase	%	Total number of sites
Aquilegia vulgaris	30	156	126	80.8	226
Dactylorhiza baltica	36	106	70	66.0	174
Malus sylvestris	29	93	64	68.8	137
Nymphaea candida	9	70	61	87.1	96
Silene tatarica	6	54	48	88.9	69
Orchis mascula	16	62	46	74.2	102
Pulsatilla patens	29	74	45	60.8	190
Diphasium complanatum	9	51	42	82.4	78
Rosa tomentosa	1	37	36	97.3	40
Helianthemun nummularium	6	35	29	82.9	59
Linnaea borealis	30	57	27	47.4	120
Polygonatum verticellatum	5	28	23	82.1	40
Pyrus pyraster	19	42	23	54.8	68
Berula erecta	1	21	20	95.2	36
Lunaria rediviva	2	22	20	90.9	35
Taxus baccata	9	29	20	69.0	60
Juncus balticus	0	17	17	100.0	37
Cucubalus baccifer	16	33	17	51.5	54
Jovibarba sobolifera	29	45	16	35.6	98
Gymnadenia conopsea	24	39	15	38.5	113
Nymphaea alba	8	22	14	63.6	33
Lathyrus montanus	2	15	13	86.7	23
Orchis militaris	15	28	13	46.4	60
Iris sibirica	21	34	13	38.2	68
Onobrychis arenaria	3	15	12	80.0	30
Trifolium alpestre	5	17	12	70.6	23
Cenolophium denudatum	8	20	12	60.0	35
Serratula tinctoria	10	22	12	54.5	36
Liparis loeselli	5	16	11	68.8	29
Gentiana crutiata	11	22	11	50.0	43
Lilium martagon	7	17	10	58.8	29
Allium ursinum	10	20	10	50.0	34

Table 2. Species showing a decrease in the number of sites recorded as new

Species	The number of sites (1891-1920)	The number of sites (1951-1980)	Decrease	%	Total number of sites
Isoetes lacustris	22	3	19	86.4	33
Digitalis grandiflora	20	7	13	65.0	50
Lycopodiella inundata	15	4	11	73.3	29
Lobelia dotrmana	19	8	11	57.9	42
Corallorhiza trifida	26	15	11	42.3	56
Stellaria crassifolia	16	6	10	62.5	30
Isoetes echinospora	9	0	9	100.0	15
Aster trifolium	8	0	8	100.0	11
Viscum album	13	5	8	61.5	29
Pedicularis sceptrum-carolinum	17	8	8	47.0	49
Salix myrtilloides	22	14	8	36.4	65
Botrychium multifidum	25	17	8	32.0	59
Saxifraga hirculus	17	10	7	41.2	51
Gladiolus imbricatus	32	25	7	21.9	91
Sparganium gramineum	6	0	6	100.0	7
Gagea pratensis	7	1	6	85.7	11
Montia fontana	9	3	6	66.7	18
Diphasium tristachium	11	5	6	54.5	23
Littorella uniflora	7	2	5	71.4	12
Hammarbia padulosa	9	4	5	55.6	28

and a slightly alkaline (soil reaction number 6.5) soil reaction, besides moderately rich in nitrogen (nitrogen number 3.9). The receding species go mainly with acid and moderately acid (soil reaction number 3.8) substrates and soils having little nitrogen (nitrogen number 2.7). Thus, the rare species preferring neutral substrates moderately rich in nitrogen tend to increase, whilst those favouring acid soils with little active nitrogen tend to decrease (Fig.2, and 3).

The marginal species, for which the number of sites has varied considerably, go with definite plant communities. As to freshwater species, those representing eutrophic communities have increased considerably (*Nymphaea candida*, 61 site; *N. alba*, 14 sites), while those of oligotropic communities (*Littorelletalia*) recorded as new are decreasing (*Littorella uniflora*, 5 sites; *Isoetes setaceae*, 19 sites; *I. echinospora*, *Lobelia dortmana*, 11 sites). A lot of rare species are associated with wetland biotopes of reeds, spring-laden sites, fens and sphagnum bogs. In the above mentioned biotopes there has been an increase in calciphilous species (*Liparis loeselii*, 11 sites; *Carex davalliana*, 7 sites; *Schoenus ferrugineus*, 6 sites; (*Caricion davallianae*) *Cladium mariscus*, 7 sites; *Teucrium scordium*, 7 sites (*Phragmitetea*, *Caricon elatea*)). The number of sites of the species preferring acid substrate decreases or remains constant (*Lycopodiella inundata*, 11 sites; *Hammarbia paludosa*, 5 sites; (*Rynchosporion albae*)). In the wetland sites a reverse case, i.e. an increase in individual species of oligotropic substrates, is also observed (*Juncus balticus*, 17 sites (*Ericion tetralix*).

In mesotropic meadows (*Molinio-Arrhenetheratetea*) there has been a significant increase in *Dactylorhiza baltica* (70 sites), *Iris sibirica* (13 sites), *Serratula tinctoria*, 12 sites, but a decrease in *Gladiolus imbricatus* (*Molinion*), 7 sites, although the occurrence of the species mentioned is rather frequent.

As to boreal coniferous forest communities (*Dirano-Pinion*), some representative species tend to increase (*Linnaea borealis*, 27 sites; *Lonicera caerulea* (6 sites)) while others decrease (*Corallorhiza trifida*, 11 sites; *Diphasium tristachium*, 6 sites). All these plants prefer acid substrates.

During the 20th c. the number of sites of rare plant species associated with deciduous forest plant communities has increased considerably. Here are the most typical ones advancing rapidly: *Aquilegia vulgaris*, 126 sites; *Malus sylvestris*, 64 sites; *Crataegus lindmanii*, 7 sites; *C. curonica*, 6 sites; (*Querco-Fagetta*), *Allium ursinum*, 10 sites; *Lilium martagon*, 10 sites; *Ranun-*

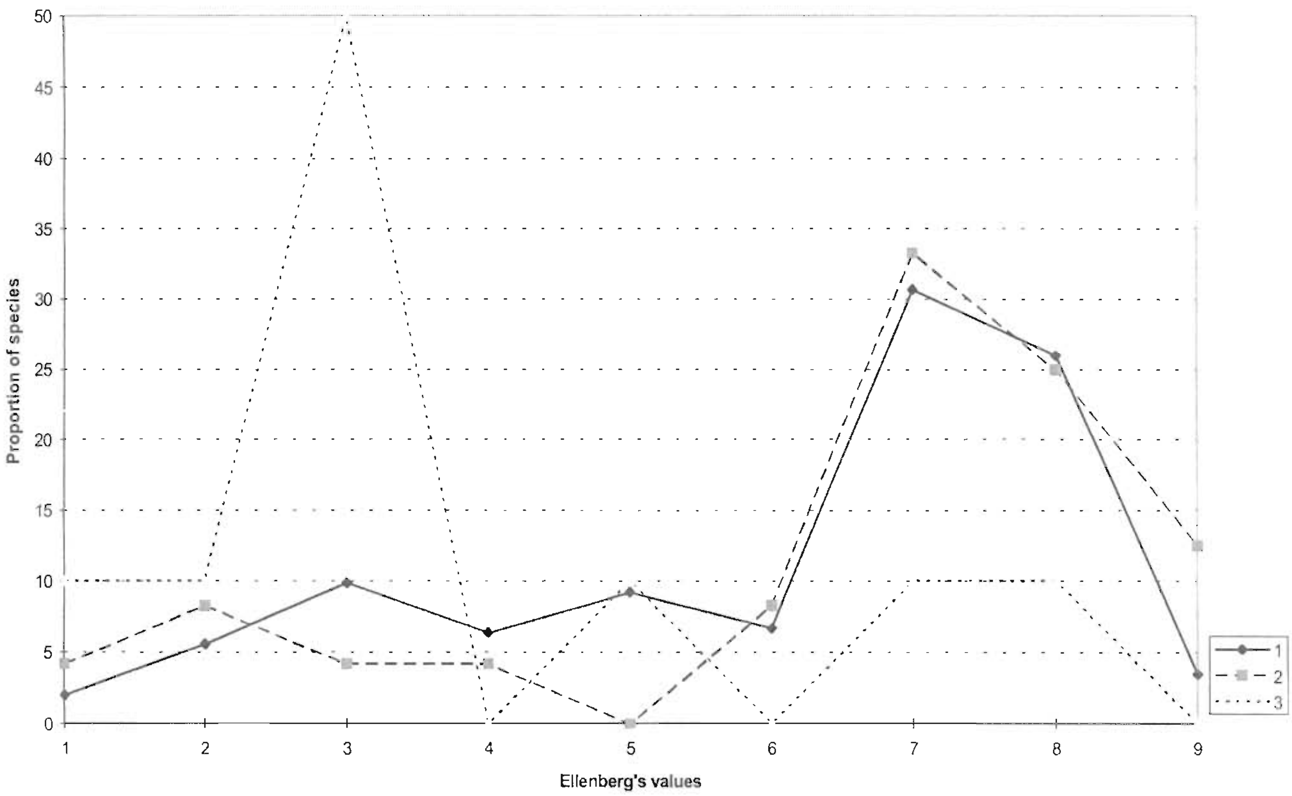

Fig. 2. Soil reaction for the Latvia's flora in general (1), for the advancing (2) and receding (3) rare species

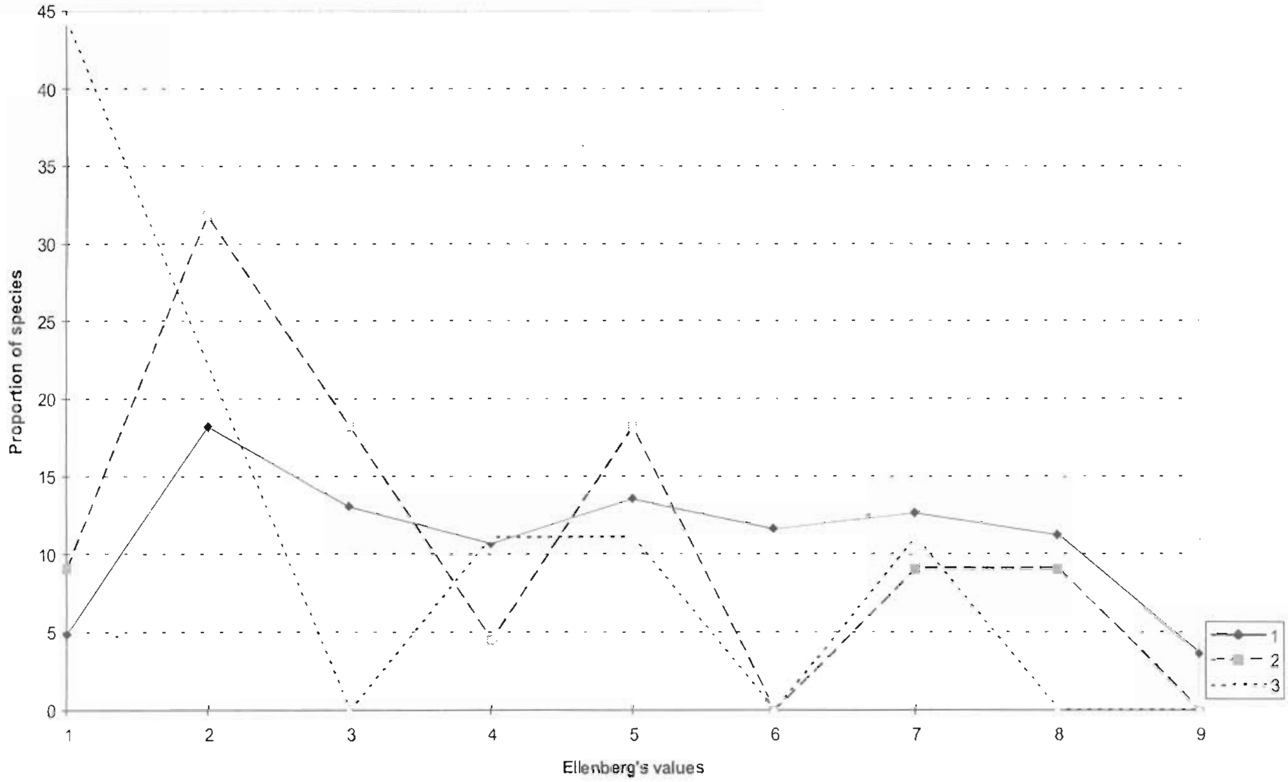

Fig. 3. The quantity of nitrogen for the Latvia's flora in general (1), for the advancing (2) and receding (3) rare species

culus lanuginosus, 9 sites; (*Fagetalia*), *Galium intermedium*, 5 sites; *Anthruscus nitida* (*Alno-Padion*), 9 sites, etc. For none of the species representing deciduous forests there has been a noticeable decrease in the number of sites.

Here are some more, supposedly, significant changes in the number of sites of rare plant species. There has been no increase in the species representing halophytic meadow communities (*Asteretea*, *Armerion maritimae*): *Aster tripolium*, *Armeria maritima*). However, there has been an increase in the species representing these on sandy sites (*Armerion elongatae*): *Silene tatarica*, 48 sites; *Armeria vulgaris*, 8 sites. The same is true for the species typical of xerophyte alkaline meadow communities (*Festuco-Brometea*, *Brometalia*, *Mesobromion*): *Helianthemum nummularium*, 29 sites; *Orchis militaris*, 13 sites; *Gentiana cruciata* 11 sites; *Onobrychis arenaria*, 12 sites; etc. There has also been an increase in the species representing these growing at forest edges and in glades (*Geranion sangunili*): *Trifolium alpestre*, 12 sites.

The number of sites has increased for temperate submeridional, suboceanic European species, but remained constant or decreased for boreotemperate, suboceanic, continental, but most of all for circumpolar species. Typically enough, among the species tending to increase we find a high proportion of nanophanerophytes and phanerophytes (*Crataegus*, *Rosa*, *Taxus*, *Carpinus*, *Malus*, *Pyrus*, *Lonicera*).

Naturalization of Exotic Species

At present, the number of vascular plant species in the Latvia's flora is nearly 1,700 (Табака и др., 1988) and almost one third of them represent exotic ones introduced in Latvia by man (Laiviņš, Zundāne, 1989). The exotic species come predominantly from the three geographical regions: Central and Southern Europe, Northern America, Eastern Asia (the Far East). Following the historical period and the way of introduction, the exotic plant species fall conveniently into 4 big groups. The oldest "immigrants" are called archeophytes, known to have been introduced in Latvia by the 17th c. (the period of prosperity of the Duchy of Kurland). The newcomers of subsequent periods (150 species) are known as neophytes, the exact time and way of introduction is in most cases unknown. Among the synantropic species there is a good deal of ergasigophygophytes or runaways from parks and gardens. Over the last decades there has been a considerable increase in ephemerophytes (more than 170 species) found along railways, highways, in the port areas, on the substrates heavily impacted by man. These species often fail to spread as they have not yet adapted themselves to the local environment. However, this should be regarded as a premonition of what we may expect in the future when a real invasion of exotic plants is likely to happen. The dynamics an increase in exotic plant species over the last 200 years is a proof of it. An increase in the number of neophytes over this period is fairly uniform, while that for ergasigophygophytes (runaways) and ephemerophytes is more pronounced (Fig. 4.).

Synantropic species get naturalized mainly in slightly acid and neutral as well as nitrogen-moderately-rich-or rich substrates (Fig. 5, and 6.). For archeophytes the average soil reaction number is 6.2; for runaways, 6.6; for neophytes, 7.0 (for the Latvia's flora on average, 6.1). The nitrogen number for neophytes is 5.7; for archeophytes, 6.0; for runaways, 6.2 (for the Latvia's flora on the average, 4.7).

Quite a lot of synantropic species, especially trees and shrubs, have accomodated to semi-natural forests (mainly urban forests). The tree species now common in Latvian forests:

European species - *Sambucus racemosa, S. nigra, Sorbus intermedia, S. hybrida, Acer pseudoplatanus, A. tataricum, Cerasus avium, Lonicera tatarica, Prunus divaricata* u.c.; Central Asian species – *Cotoneaster lucidum, Caragana arborescens, Impatiens parviflora, I. glandulifera*; East Asian species – *Berberis thunbergii, Lonicera ruprechtiana, Rosa rugosa, Scorbaria sorbifolia, Ulmus pumila*; North American species – *Amelanchier spicata, Acer negundo, Symphoricarpos rivularis, Robinia pseudoacacia Physiocarpos opulifolius, Parthenocisus quinquefolia, Aronia prunifolia 'Floribunda'*.

The exotic tree and shrub species are found, for the most part, in less stable forest stands exposed to different environmental impacts where species succession takes place, for example, pioneer stage stands of pine and birch. Drained forests, and As (*Myrtillosa mel.*), Ap (*Mercurialiosa mel.*), Ks (*Myrtillosa turf. mel.*) Kp (*Oxalidosa turf. mel.*) forest site types in particular, represent a site favourable for exotic species. In similar dynamic forest biotopes the exotic species are often found in the undergrowth, forming continuous thickets, which is a sign of bush encroachement. Owing to the ability of these species to regenerate themselves and spread rapidly, they compete against the principal tree species for the space and nutrients. For these reasons, the brushwood of exotic

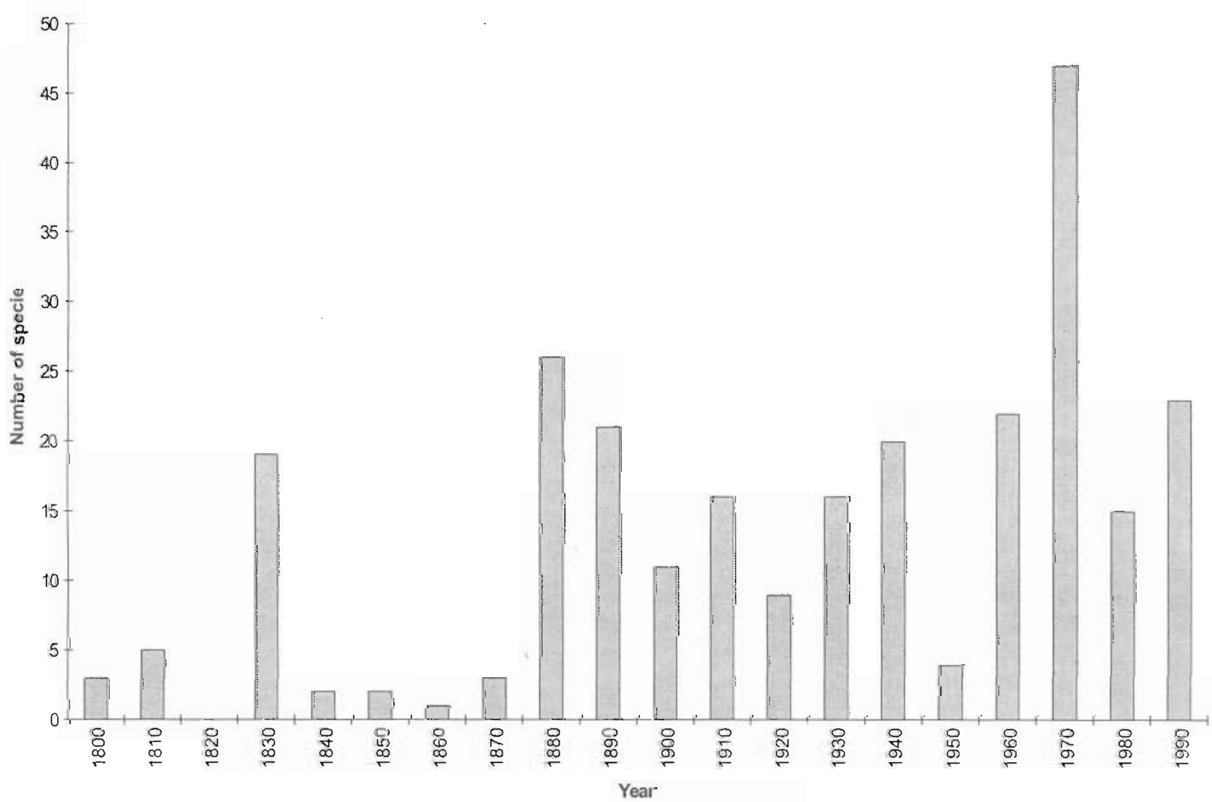

Fig. 4. The dynamics of ergasigophygophytes (runaways) and ephemerophytes in Latvia

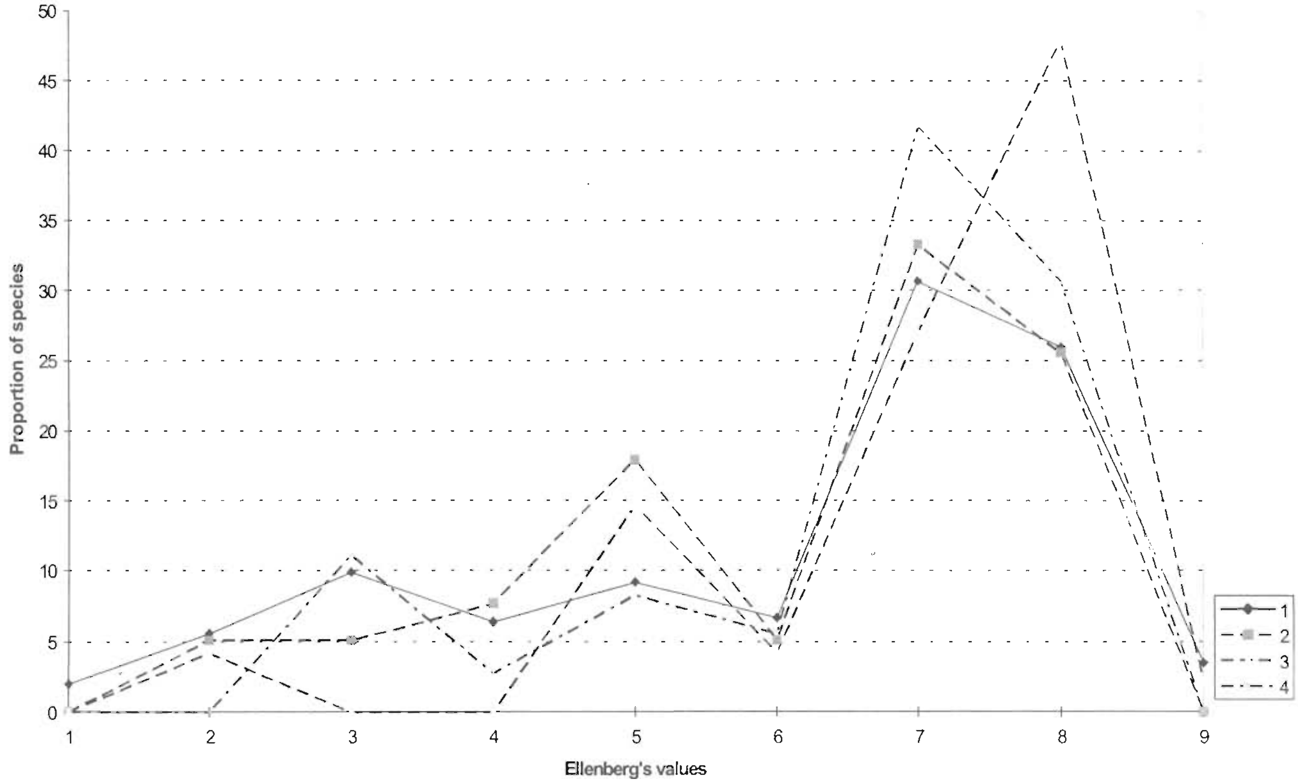

Fig. 5. Soil reaction for the Latvia's flora in general (1), for archeophytes (2), for neophytes (3) and ergasigophygophytes (4)

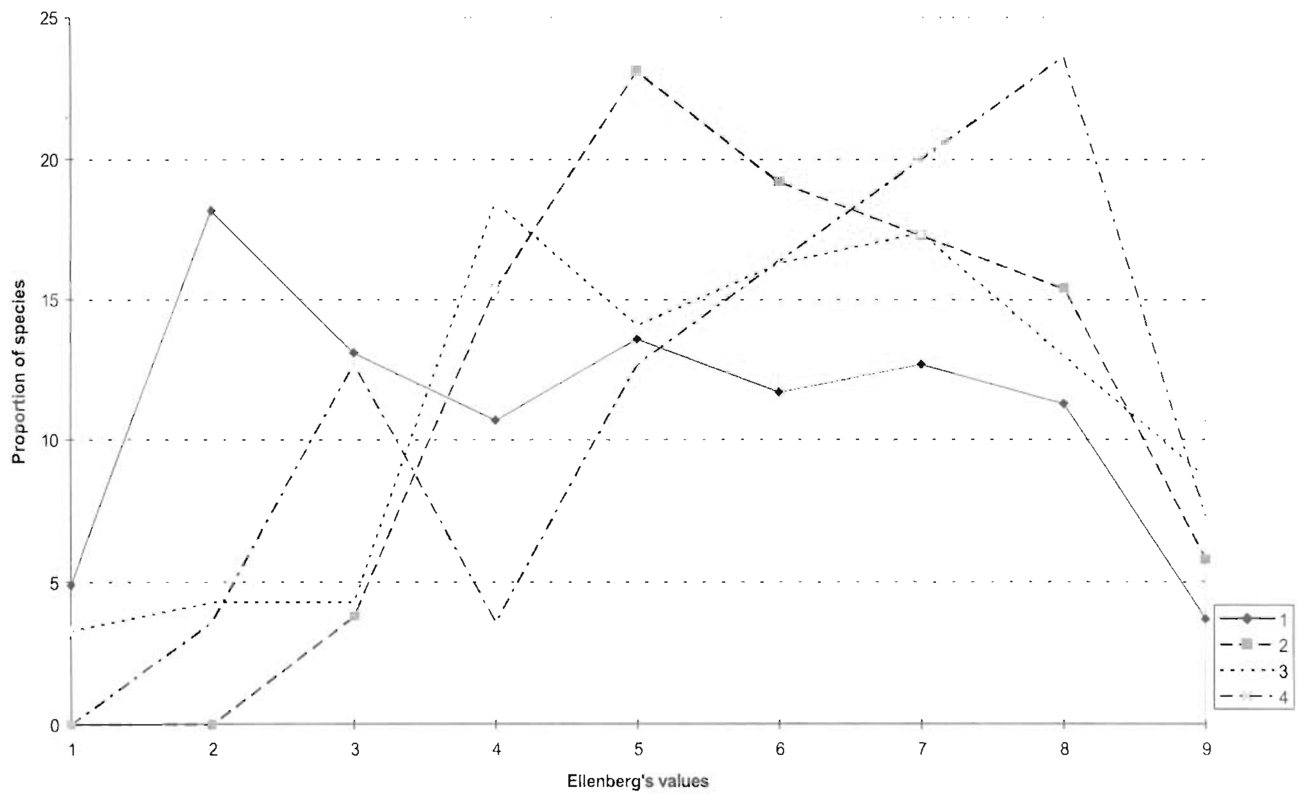

Fig. 6. Nitrogen availability for the Latvia's flora in general (1), for archeophytes (2), for neophytes (3) and ergasigophygophytes (4)

species in the understory may become a factor adversely affecting the performance of high value and productive stands of conifers.

Rare species and the transformation of vegetation

Over the 20th c. the dynamics of the sites of rare plant species detected as new, as well as the naturalization intensity of exotic species, reveal a number of important processes under way in the world of plants and in the environment as a whole.

Firstly, the number of sites increases for the species preferring moderately acid or neutral substrates; the number of sites remains unchanged or tends to decrease for the species preferring acid oligotropic substrates. The variations over time in the number of sites of rare species testify to a progressive eutrophication of water-logged (wetland) biotopes (freshwater reservoirs, bogs) as well as forest soils. The exotic species, too, naturalize predominantely in slightly acid or neutral, nitrogen moderately-rich or rich substrates.

Secondly, the proportion of temperate, submeridional (as well as meridional) suboceanic European plant species and communities steadily increases. This tendency is illustrated by a representative sample of definite plant communities and rare species. The proportion of species representing suboceanic summergreen deciduous (*Querco-Fagetea*) and subcontinental and continental sarmentaceous and even pontic herbaceous increases, while that of boreal coniferous communities (*Vaccinio-Piceetae*) diminishes.

Thirdly, a number of wetland biotopes, e. g. halophytic meadows, spring-laden sites, etc. are rare and of small size, and the species representing these biotopes in Latvia do not increase their life room. So, it is necessary to promote in every way the conservation of these biotopes and the rare species found there.

In general, the dynamics with time in the number of sites of rare species and the naturalization intensity of exotic species testify to the shifts in the ranges of natural occurrence of vegetation, apparently stimulated by the global warming of the climate, resulting in a progressive eutrophication of the environment. In Latvia, and possibly all over the Baltic region, the role of the deciduous forest biome is increasing while that of the boreal conifers is decreasing.

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ДИНАМИКА МЕСТОНАХОЖДЕНИЙ РЕДКИХ МЕСТНЫХ И ЧУЗЕМНЫХ ВИДОВ РАСТЕНИЙ И ИЗМЕНЕНИЕ СРЕДЫ В ЛАТВИИ

М. Лайвиньш

Резюме

Для выявления изменений среды и растительности на территории Латвии использованы данные по инвентаризации местонахождений (всего 4456) редких местных и чуземных видов растений во флоре Латвии за последние 200 лет. Анализ данных показывает, что весьма интенсивно увеличивается распространение видов, предпочитающих слабо кислый и нейтральный субстрат, а сокращается или не изменяется число местонахождений видов растений, растущих на кислом олиготрофном субстрате. Распространение увеличивается видов, характерных для лесов летнезеленых лиственных лесов (*Querco-Fagetea*) и субконтинентальных травяных сообществ (*Festuco-Brometea*). Это указывает на усиление процессов эвтрофикации среды (потепление климата, умеренное загрязнение соединениями азота и др.) и постепенном увеличении элементов неморального и сокращение элементов бореального хвойного биома в лесах Латвии, а следовательно и всей Балтии.

Ключевые слова: редкие виды растений, чуземные виды растений, местонахождения, растительные сообщества, среда, эвтрофикация