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Necessity and reality of monitoring threatened European vascular plants

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Abstract Species monitoring is the regular observation and recording of changes in status and trend of species in a certain territory. The primary purpose of monitoring is to collect information that can be used to examine the outcomes of management actions and to guide management decisions. Here, we analyze plant species monitoring to provide a first overview on efforts made to monitor trends in vascular plant biodiversity in Europe. Our study is based on an assessment of 63 plant monitoring schemes from Europe (collected into a database "DaEuMon"), and 33 schemes found with literature screening. Altogether, the monitoring schemes cover 354 vascular plant species, of which 69 are listed in Annex II of the EU Habitats Directive (= EU protected species; Annex II includes 420 species). In most cases, an EU protected plant species occurs in 3 countries but is monitored in only 1 country. Scientific interest was the main reason for launching a monitoring scheme in 21% of the schemes from the database, but in 58% of the schemes from the literature survey. The current schemes collect insufficient data particularly on the dynamics of the extent and distribution pattern of species. We conclude that planning to publish monitoring data when designing a scheme would improve the quality and general effect of monitoring programs. The needs to cover the taxonomic diversity and the integration of different scales, as well as the inclusion of monitoring in the context of different types of sustainable management would require a strong emphasis in the development of monitoring schemes.

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Introduction

Species monitoring is the regular observation and recording of changes in status and trend of species in a certain territory. The primary purpose of monitoring, if not launched purely for scientific interest, is to collect information that can be used for development of conservation policy, to examine the outcomes of management actions and to guide management decisions (Niemelä 2000). In the Convention on Biological Diversity signatory countries have committed themselves to reduce the current loss of biodiversity (Nimis et al. 2002). The EU adopted the more ambitious target to halt biodiversity loss by 2010 (European Council 2001). In practice, the EU focuses its efforts on protection of various habitat types and on species listed in Annex II of the Habitats Directive (hereafter 'EU protected species'). These species are considered rare and/or threatened in Europe and monitoring of their populations is essential in order to estimate success of conservation efforts at the EU level. The Habitats Directive, one of the most important conservation tools in Europe, legally requires EU Member States to monitor and report on status and trends in the 420 plant species listed in Annex II.

Monitoring results have also regularly contributed to other conservation policies. For instance, the changes in the allocation of species to Red Book categories are generally based on (and in the case of most rare species, require) monitoring data. In many countries, such changes imply also changes in the legal status of the species. Therefore, there is a long and considerable tradition on species monitoring in Europe (e.g., Rich and Woodruff 1996). So far each European country has designed its own monitoring system and few recent European level overviews on species monitoring have been published. All of them concern only animals, most specifically birds (e.g., BirdLife International 2004) and some groups of insects (e.g., Southwood et al. 2003). This is surprising, considering the high indicative quality of plant species and the fact that the diversity of plants is one of the best available predictors of diversity of other taxa (Sala et al. 2006; Pereira and Cooper 2006). Almost the only plant species group that is well covered and for which trends in abundance and range are available is orchids (Jacquemyn et al. 2005; Kull and Hutchings 2006, etc.).

However, state-supported monitoring programs have appeared more recently, mainly since the 1970s-80s. For instance, Sweden has a unified national environmental monitoring program since 1987 (Inghe 2001). Systematic work with threatened plants in Finland started in 1970s, mainly by WWF-Finland; state participation began in 1983, and since 1991 the Finnish Nature Conservation Act has obliged authorities to monitor populations of threatened species (Ryttari 1997). State programs for monitoring in Poland started in 1991 and in Estonia in 1994 (Kull 1999), both cover also plant species. The Program of Biodiversity Monitoring in Switzerland has monitored vascular plant species richness since 2001 (Plattner et al. 2004).

Without overviews on the reality of plant monitoring, it is not possible to evaluate to which extent plant monitoring meets policy needs. Here, we provide a first overview of vascular plant monitoring in Europe. We used data from a survey of monitoring schemes across Europe conducted recently (Henle et al., this volume) within the project EuMon (European-wide monitoring methods and systems of surveillance for species and habitats of Community interest; http://eumon.ckff.si). In addition, we based our analysis on a literature search. We assessed to which extent plant species have been monitored in Europe, whether species of the Habitats Directive are targeted in national monitoring scheme, and to which extent monitoring schemes have been launched primarily for conservation reasons.

Material and methods

Background

There are three basic groups of parameters at the population level that can be estimated during monitoring (see also Campbell et al. 2002): (1) population size in terms of number of individuals or population density (e.g., Pfeifer et al. 2006); (2) the extent of a population, i.e. area that a population occupies (e.g., Jones 1998; Brzosko 2003); and (3) population viability, i.e. any estimation of plant size distribution, their reproductive success, age and/or stage structure of a population, etc. (e.g., Jones 1998; Brzosko 2003; Janečková et al. 2006). These three categories complement each other and could/should be used in combination when assessing the dynamics of a population in detail. As a straightforward estimate of population size, the number of individuals is the most direct and useful characteristic of these three when used alone.

On a national or regional level, the quantification of the dynamics of individual populations are usually neglected due to a need to generalize the results. In a wider spatial context the aspects that determine metapopulation or metacommunity dynamics could provide useful information in addition to the extent of the species distribution. Hence, the following characteristics appear to be of primary importance for regional/national level monitoring (see also Pereira and Cooper 2006; Sammul et al. this volume): (1) the distribution range; (2) the pattern of spatial distribution of species (the connectivity/isolation level between populations); (3) the ratio between populations with positive and negative abundance trends (or spatial extent).

In combination, these six groups of parameters provide categories against which it is possible to evaluate what sort of information various monitoring programs collect.

Dataset and variables

We collected data on plant species monitoring schemes operating or being designed in Europe. We have developed a questionnaire containing eight questions on basic features of monitoring schemes and 33 questions on various properties of the species monitoring schemes. The electronic form of the questionnaire was made publicly available in 2005 at the EuMon project website as an online data entry interface (http://eumon.ckff.si/monitoring). Between 1 February and 31 August, 2006, 1675 letters were sent to coordinators of monitoring schemes, ministry officials, and representatives of other stakeholder groups involved in habitat monitoring to ask filling in the questionnaire online. The information entered by the coordinators and other interested parties were then validated and organized into the 'DaEuMon' database. All the schemes and some general statistics are available on the EuMon website http://eumon.ckff.si and the database is continuously updated. The subtotals used in this article were extracted on August 21, 2007. Since setting up the online questionnaire in January 2006, to August 2007, 399 species monitoring schemes have been inserted into the database, from which 63 schemes represent monitoring of vascular plants. The database allows estimating whether a monitoring scheme estimates the size of a populations, the extent of a populations, regional extent of a species, and viability of plants in population.

Literature search

To assess similarities and differences between our database and monitoring research published in the scientific literature, we searched in web databases ISI Web of Knowledge and Google Scholar. We made two searches: firstly, using EU protected plant species scientific names as a search criteria, and secondly, using occurrence of any of the keywords *plant monitoring* and *long-term population dynamics*. The latter criteria comprised therefore also schemes that did not include monitoring of EU protected species. We considered papers published during 1980–2006 and limited the dataset to articles containing monitoring studies with at least 5-year duration conducted in Europe.

Altogether 33 studies were found that met these criteria (Appendix 3). From these published papers the following parameters were extracted:

– aim of the monitoring (species biology/ecology, management/restoration/other conservation project, or development of monitoring methods);
– type of the study (autecological study, monitoring study, estimation of climate change effects, or plant translocation experiment);
– method of population monitoring (marking and measurement of individual plants, or population structure);
– method of statistical analysis (basic: correlative, ANOVA etc.; advanced statistics: GLM etc., PVA and LTRE);
– population size characteristic (density within plots, total population size, or not estimated);
– plant viability estimated (yes or no);
– extent of the whole population estimated (yes or no).

Hence, the literature evaluation enables for test whether species abundance, extent of a population, or viability of plant populations have been estimated.

Results

DaEuMon database analysis

Of 420 EU protected vascular plant species, 69 species (i.e. 16%) are monitored (Appendix 2). A species inhabits on average 4.4 (median 3) countries and is monitored in 1.6 (median 1) countries (Appendix 1). Thus, less than half of the countries, where a species has been recorded, actually monitor it. There is a positive correlation between the number of countries a species inhabits and the number of countries it is monitored. These monitored 69 species belong to 29 families, whereas all the EU protected species represent 66 families (Appendix 2). Some of the families seem to be under-represented, as e.g. Fabaceae, Amaryllidaceae, and Plumbaginaceae.

Beside EU protected species, the questionnaire for database enabled to list other species that different countries and schemes monitor. Here 354 species of vascular species have been listed from 75 families. 40 species of Orchidaceae is certainly the highest number of species per family, but more than 10 species have been listed from families Fabaceae, Caryophyllaceae, Ranunculaceae, Asteraceae, Cyperaceae, Liliaceae, Poaceae, Rosaceae and Scrophulariaceae.

The earliest mapping programs in the database started in 1800, but in more than 50% of the schemes the starting point is 1994 or later.

Over the half of the monitoring schemes were launched because of legislative reason (either national law–48% or EU directive–11%), but also because of interest to species biology/ecology (21%), followed by conservation issues and other reasons (Table 1). Almost all (92%) monitoring schemes estimated the size of populations, the extent of populations is estimated in 43%, and viability of populations in 19% of schemes. 57% used methods of counting the number of plants in a population; 19% determined presence/absence of a species; 11% and 13% of schemes used phenology and age/size structure, respectively, to characterize a population. There is no data about possible estimation of pattern of spatial distribution range or evaluation of the ratio between populations with positive and negative abundance trends. However, 52% of schemes listed the evaluation of changes in species distribution range among their goals.

Site choice is predominately made by expert knowledge or by exhaustive sampling, and only in few cases by random choice (Fig. 1). Only 10% of schemes state that their sampling design allows probability assessment. 20% of schemes have not marked the minimum annual change that their scheme can statistically detect (Fig. 2). 95% of sampling sites are located either entirely or partly in legally protected areas. Most of the work is done by few professionals per scheme (average 15.8, median 3), and volunteer involvement is on a low level (Fig. 3), except in some countries as United Kingdom where hundreds of volunteers do the monitoring.

Monitoring data were analyzed predominantly by simple descriptive statistics (48%); 22% used advanced statistics, whereas 13% were not analyzed at all or were analyzed by someone else (Table 2).

Literature analysis

Of the 33 reviewed studies 58% seemed to be initiated purely because of interest to species biology/ecology (Table 1). However, 39% noted specific conservation issues as the reason for the study. 73% were typical studies of species autecology and 18% were monitoring studies. Population size and viability were targeted in most studies (88% and 97%, respectively), whereas extent of population was targeted only in 30% of the studies. 84% of studies followed the fate of marked or mapped individual plants, the rest (16%) used a description of population structure. The population size is estimated in 92% of studies. Viability and extent of populations is monitored in 43% and 19% of studies respectively.

Table 1 Main reasons for launching the monitoring scheme

Main reason for launching	DaEuMon		Literature	
	No	%	No	%
Legislative (national law)	30	48		
Legislative (EU directive)	7	11		
Management/restoration/other conservation project	9	14	13	39
Species biology/ecology	13	21	19	58
Methodical test			1	3
Other reason, or blank	4	6		
Total	63		33	

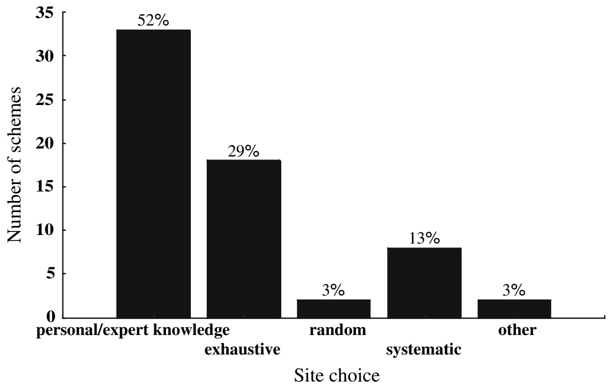

Fig. 1 Methods of site selection in monitoring schemes

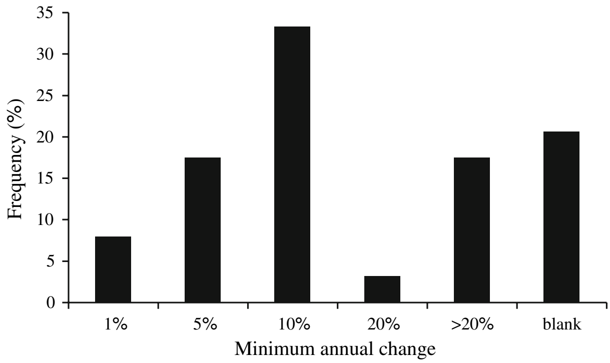

Fig. 2 Minimum annual change the monitoring schemes declare to detect

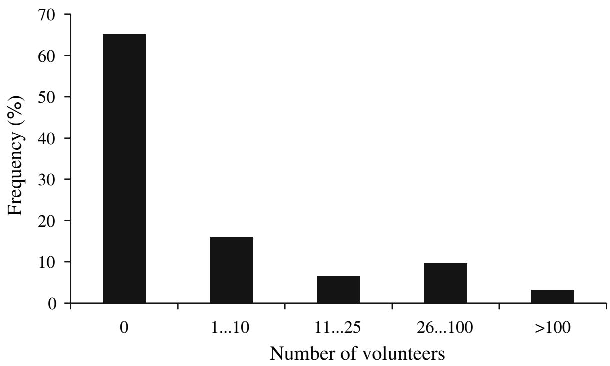

Fig. 3 Volunteer involvement in monitoring schemes

Regarding data analysis, basic descriptive statistics was most common (61%), followed by population viability analysis and life-table response (LTRE) analysis (15%, together) and advanced statistics (15%), whereas 9% did not use statistics at all (Table 2).

Table 2 Analysis methods used in monitoring schemes

Analysis method	DaEuMon		Literature	
	No	%	No	%
Basic (graphics, descriptive statistics, linear regression)	30	48	20	61
Advanced statistics (GLM, GAM, mixed models, time series, discriminant analysis etc.)	14	22	5	15
PVA & LTRE			5	15
Data are analysed by someone else	2	3		
Not analysed	6	10	3	9
Other	11	17		
Total	63		33	

Discussion

Our analysis reveals several discrepancies between the actual situation in monitoring of plants in Europe and the aims that the monitoring programs set. Pereira and Cooper (2006) have previously mentioned three main constraints of biodiversity monitoring: incomplete taxonomic and spatial coverage; lack of compatibility between data sets owing to different collection methodologies; and insufficient integration at different scales. We argue that with respect to all these three aspects the monitoring of plants currently has several shortcomings.

Taxonomic and spatial coverage

Incompleteness of taxonomic coverage of monitoring programs is a global problem (Mace 2005). Our analysis of plant species monitoring reveals that a large number of EU protected species are actually not monitored (see Appendices 1 and 2) and an even larger number of species are monitored only in very few countries. As there are no agreed indicators of plant diversity available yet, we have no reason to believe that species that currently are monitored can be used as a proxy for overall diversity trends. Hence it could be argued that current monitoring effort does not enable to estimate whether large political targets (e.g. 2010 target, or Common Agricultural Policy biodiversity targets) are met or whether EU directives aiming at nature conservation are successful.

On a national scale the situation is somewhat better. There are countries for which atlases of the flora of the country are available with censuses from various time periods (e.g., Preston et al. 2002; Kukk and Kull 2005). These can be used for estimation of overall trends (e.g., Sammul et al., this volume). A few attempts have been made to compare different countries (e.g., see Kull and Hutchings 2006) or different regions (Jacquemyn et al. 2005). Still, extrapolation from results of observations of single populations to even a country level or from country level to EU level is at the current level of monitoring of species insufficient. There exist methods that would allow for such extrapolations (e.g., meta-analysis), but these are underutilized. The generalisations from local to national and national to pan-European trends of abundance and range of plant species should be given much higher priority if we wish to base our further conservation decisions on the analysis of current situation and/or dynamics of biodiversity.

Constraints from data

Since monitoring of biodiversity requires a large effort, it has been proposed to monitor only few elements that have relevance to key issues (Gaines et al. 1999). This has lead to construction of composite Biodiversity Trend Indicators (Gregory et al. 2005; de Heer et al. 2005), which should help to reduce the effort. There is a large expectancy associated with several large European projects which aim at establishing indicators of biodiversity (e.g. BioScore and SEBI 2010), but the results of these projects are yet to be made public. However, the use of biodiversity indicators is largely limited as they can be relied on only in situations and on scales where they have been developed and tested (Weaver 1995; Quayle and Ramsay 2005). Moreover, the use of composite indexes never enables estimation of the dynamics of a particular species. The latter can only be estimated with monitoring of the species of interest. Hence, to know the actual trend of species that are of importance, such as species of community interest in Habitats Directive, there is no other way than to actually monitor their populations.

Above we described three types of information on population level and three types of information on either national or regional level that could be used for monitoring. While estimation of abundance prevails in monitoring, and extent of populations was estimated in 30–40% of studies, there was less than 20% of studies listed in DaEuMon which would estimate viability of plants while the amount of such studies in literature was over 95%. Moreover, very high proportion (84%) of published studies follow the fate of marked or mapped individual plants. This shows that scientific studies are generally more complicated and much more oriented towards detailed measurements of individual plants than more general monitoring schemes aiming toward conservation. It may also be taken as an indicator of domination of ecological studies (e.g. study of local causes of population decline or species habitat requirements) over biogeographic ones (e.g. factors of large scale dynamics and distribution or reaction of plants to climate change) concerning rare and threatened plant species. However, this also means that monitoring data is not sufficiently utilized and monitoring programs do not take advantage of new developments in data analysis and modelling methods (e.g., PVA).

Surprisingly, however, there are only a few studies that would aim at estimation of species fate at regional or international level. Our analysis shows that the parameters that would enable for estimation of such large-scale changes (distribution range; pattern of spatial distribution of species as the connectivity/isolation level between populations; ratio between populations with positive and negative trend of abundance or spatial extent) are hardly evaluated at all. It would be simple to conclude that the issue originates from not emphasising the importance of large-scale dynamics in species preservation (Freckleton and Watkinson 2002), but it would be too simplistic. It is well-known that gathering information about European (not to mention global) distribution of species is extremely difficult and sometimes even impossible (Baillie et al. 2004). Moreover, as many monitoring schemes are launched only in order to estimate the effect of certain projects, the global perspective could be missing starting from the design and financing of the project. At least national monitoring projects and EU-funded projects should have in the future a clear strategy for publishing of their results and making the estimations of species trends available for public use and evaluation of biodiversity trends (e.g., Guralnick et al. 2007). However, the contemporary practice often shows the abandonment of the monitoring with the end of the project, which makes the efficiency of the use of funds somewhat doubtful.

Absence of systematic data analysis and reporting has been noted already formerly (Ryttäri et al. 2003) and seems to be the problem especially in national monitoring schemes where data is sometimes not analysed at all (Table 2). We emphasise that solution to this problem could be relatively simple. Not always the data even has to be analysed by site managers or volunteers doing the actual monitoring. Instead, if the monitoring methods and results were publicly available, e.g., on a specific web page, the information would not be hidden anymore, and public and/or academic feedback would ensure a mechanism for an improvement of the whole monitoring process.

Integration at different scales

We found a surprisingly small number of monitoring studies launched in respect to conservation, despite the fact that it is usually conservation bodies funding these programs. As EuMon database (DaEuMon) shows, one of the strongest driving forces is actually the pressure from either local or EU-level legislations. There is a threat, however, that monitoring schemes designed to only meet legal obligations would become too simplistic. As it currently stands, we can state that even though there are no signs of oversimplification of botanical monitoring, there are no generalisations either and the potential of data of plant monitoring to be used in conservation planning is underutilized. We already questioned the representativity of selection of species for monitoring. Here we would like to emphasise that selection of monitoring sites even further reduces the reliability of scaling-up from monitoring data to overall dynamics of plant diversity and state of the environment.

Since most of sampling sites are located either entirely or partly in legally protected areas, the schemes obviously cannot describe the changes in other landscapes, such as agricultural or urban areas. Whether conservation is given any tasks outside of protected areas varies largely between countries. However, monitoring of species predominantly in protected areas assumes that biodiversity can be protected with those reserves only. Often such an assumption does not hold (Lindenmayer and Franklin 2002; Dinerstein et al. 2007).

Plant species vary largely in their habitat specificity, however, rare plants tend to be more specialised and selection of species for monitoring is for obvious reasons biased towards rarer species. Thus, unless selection of species for monitoring is given a specific task of being representative with regard to certain habitat types, judging the condition of habitats or condition of the whole flora of the region by dynamics of rare species is possible probably in only a few and quite special cases. Extracting data from monitoring of habitats for monitoring of plants is possible when reliable sampling regime with representative vegetation analyses are used and variables of habitat and populations are combined (Noss 1990). These data could balance the bias towards rare species in plant monitoring schemes, however, it is probably not enough for gathering sufficient information about overall trend of plant biodiversity. Hence, monitoring schemes need specifically address the issue of general applicability of their results.

The monitoring of biodiversity is utilized also for estimation of the overall effect of changes in habitat and landscape management. The changes in human impact in all habitats should be detectable at least on a national scale. However, currently, the existing datasets do not allow for the analysis of the impact of either sustainable or non-sustainable ways of ecosystem management practices to the species dynamics.

Publication constraints

As with any review we probably missed several important publications about monitoring of plants in Europe and the DaEuMon most probably is not a complete overview of all monitoring schemes either. However, we have a reason to believe that both these sources of data have comparable shortcomings in terms of representativity and, thus, can readily be compared to each other. Comparing the two sources of data we conclude that most of the monitoring results do not end up being published.

Monitoring schemes generally aim to describe long-term, large-scale trends. Since the additional information (besides abundance estimates) gathered about populations is often quite scarce, the data would need a long period to collect in order to get a sufficient piece for publication as a scientific article. However, even then the "normal" style of writing dictates that the manuscript should be centered around some cutting-edge scientific problem. The question whether species is decreasing or increasing is in itself hardly considered as scientific–it is rather a piece of natural history. Thus it is easy to understand why over 50% of studies using monitoring data and published in scientific journals state only some ecological problem as a cause of their initiation. Moreover it seems that when scientific publications use monitoring data the detection of whether the species is doing well or not in nature is completely irrelevant for large part of the authors and the dynamics of the species or its status (whether it is increasing or decreasing species) are not even reported.

Conclusions

Based on the analysis above, we can conclude that publishing of monitoring data would generally improve the quality and general effect of monitoring programmes. As a simple question of whether species is decreasing or increasing in abundance concerns a topic in natural history rather than a scientific problem, it is understandable that such answers cannot be usually found in scientific literature. Hence, alternative ways of making this information available should be utilised. A simple web portal, which would on one hand serve perhaps as a mean for data transfer for monitoring specialists and on the other hand provide information about the results of monitoring would initiate a feedback control mechanism and considerably improve the current situation where several large-scale and pan-European analyses cannot be properly carried out due to missing information. More extensive publishing and analysing of monitoring data could have huge implications on our knowledge of the status of biodiversity in Europe and enable for far more sophisticated decision-making in conservation planning.

As the Habitats Directive already has been the cause for launching of new monitoring schemes and has influenced the running ones, the EU could also emphasise the need for systematic pan-European monitoring system that would provide an assessment of how conservation targets are met. A much better coverage of the taxonomic diversity and the integration of different scales, as well as the inclusion of monitoring in different types of landscapes is essential in order to reduce the discrepancies between the necessity and reality of the monitoring work in future. It is also important to include the parameters essential for population viability estimations in compiling monitoring schemes. As there is hardly any international perspective in the planning of monitoring schemes (except for sticking with Natura 2000 species), the evaluation of trends in European diversity remains complicated and distorted.

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Appendix 1 EU protected species occurrence and monitoring in different EU countries

Species	Family	No. of countries inhabited	No. of countries monitoring (DaEUMon)	%
Alisma wahlenbergii	Alismataceae	3	1	33
Caldesia parnassifolia	Alismataceae	4	1	25
Luronium natans	Alismataceae	10	1	10
Angelica palustris	Apiaceae	8	4	50
Apium repens	Apiaceae	12	3	25
Ferula sadleriana	Apiaceae	3	2	67
Seseli leucospermum	Apiaceae	1	1	100
Vincetoxicum pannonicum	Asclepiadaceae	1	1	100
Artemisia campestris subsp. *bottnica*	Asteraceae	2	1	50
Carlina onopordifolia	Asteraceae	1	1	100
Cirsium brachycephalum	Asteraceae	5	2	40
Jurinea cyanoides	Asteraceae	2	1	50
Ligularia sibirica	Asteraceae	8	3	38
Saussurea alpina subsp. *esthonica*	Asteraceae	2	1	50
Serratula lycopifolia	Asteraceae	8	3	38
Tephroseris longifolia subsp. *moravica*	Asteraceae	2	1	50
Echium russicum	Boraginaceae	6	3	50
Myosotis rehsteineri	Boraginaceae	3	1	33
Onosma tornensis	Boraginaceae	2	2	100
Cochlearia polonica	Brassicaceae	1	1	100
Cochlearia tatrae	Brassicaceae	2	2	100
Crambe tataria	Brassicaceae	7	2	29
Erysimum pieninicum	Brassicaceae	1	1	100
Sisymbrium supinum	Brassicaceae	6	1	17
Thlaspi jankae	Brassicaceae	2	2	100
Adenophora lilifolia	Campanulaceae	10	2	20
Campanula serrata	Campanulaceae	3	1	33
Arenaria ciliata subsp. *pseudofrigida*	Caryophyllaceae	1	1	100

Appendix 1 continued

Species	Family	No. of countries inhabited	No. of countries monitoring (DaEUMon)	%
Dianthus arenarius subsp. *arenarius*	Caryophyllaceae	4	3	75
Dianthus diutinus	Caryophyllaceae	1	1	100
Dianthus lumnitzeri	Caryophyllaceae	4	2	50
Dianthus nitidus	Caryophyllaceae	1	1	100
Dianthus plumarius subsp. *regis-stephani*	Caryophyllaceae	1	1	100
Moehringia lateriflora	Caryophyllaceae	3	1	33
Petrocoptis pseudoviscosa	Caryophyllaceae	1	1	100
Eleocharis carniolica	Cyperace	7	2	29
Borderea chouardii	Dioscoreaceae	1	1	100
Aldrovanda vesiculosa	Drosaceae	6	2	33
Gentianella anglica	Gentianaceae	1	1	100
Gentianella bohemica	Gentianaceae	4	1	25
Gladiolus palustris	Iridaceae	10	3	30
Iris aphylla subsp. *hungarica*	Iridaceae	3	3	100
Iris humilis	Iridaceae	5	1	20
Dracocephalum austriacum	Lamiaceae	8	2	25
Colchicum arenarium	Liliaceae	3	2	67
Linum dolomiticum	Linaceae	1	1	100
Najas flexilis	Najadaceae	7	1	14
Cypripedium calceolus	Orchidaceae	20	5	25
Himantoglossum adriaticum	Orchidaceae	5	1	20
Himantoglossum hircinum subsp. *caprinum*	Orchidaceae	6	1	17
Liparis loeselii	Orchidaceae	18	3	17
Paeonia officinalis subsp. *banatica*	Paeoniaceae	3	1	33
Arctagrostis latifolia	Poaceae	1	1	100
Arctophila fulva	Poaceae	2	1	50
Cinna latifolia	Poaceae	4	1	25
Rumex rupestris	Polygonaceae	3	1	33
Cyclamen fatrense	Primulaceaea	1	1	100
Aconitum firmum subsp. *moravicum*	Ranunculaceae	3	1	33
Pulsatilla patens	Ranunculaceae	11	5	45
Pulsatilla subslavica	Ranunculaceae	1	1	100
Agrimonia pilosa	Rosaceae	6	2	33
Pyrus magyarica	Rosaceae	1	1	100
Galium cracoviense	Rubiaceae	1	1	100
Thesium ebracteatum	Santalaceae	7	2	29
Saxifraga hirculus	Saxifragaceae	12	2	17
Pedicularis sudetica	Scrophulariaceae	2	1	50

Appendix 1 continued

Species	Family	No. of countries inhabited	No. of countries monitoring (DaEUMon)	%
Rhinanthus oesiliensis	Scrophulariaceae	1	1	100
Tozzia alpina subsp. *carpathica*	Scrophulariaceae	5	1	20
Daphne arbuscula	Thymelaceae	1	1	100
Average		4.4	1.6	57
Median		3	1	50

Appendix 2 Families of EU protected species and the percentage of their species monitored

Family	No. of protected species	No. of monitored species	%
Alismataceae	3	3	100
Amaryllidaceae	11		
Apiaceae	19	4	21
Asclepiadaceae	1	1	100
Aspleniaceae	2		
Asteraceae	56	8	14
Blechnaceae	1		
Boraginaceae	11	3	27
Campanulaceae	9	2	22
Caryophyllaceae	37	8	22
Chenopodiaceae	3		
Cistaceae	5		
Convolvulaceae	2		
Cruciferae	33	6	18
Cyperaceae	3	1	33
Dicksoniaceae	1		
Dioscoreaceae	1	1	100
Droseraceae	1	1	100
Dryopteridaceae	3		
Elatinaceae	1		
Ericaceae	1		
Euphorbiaceae	2		
Fabaceae	15		
Gentianaceae	5	2	40
Geraniaceae	3		
Globulariaceae	1		
Gramineae	25	3	12
Grossulariaceae	1		

Appendix 2 continued

Family	No. of protected species	No. of monitored species	%
Hippuridaceae	1		
Hymenophyllaceae	1		
Hypericaceae	1		
Iridaceae	5	3	60
Isoetaceae	2		
Juncaceae	2		
Labiatae	17	1	6
Lentibulariaceae	2		
Liliaceae	10	1	10
Linaceae	2	1	50
Lythraceae	1		
Malvaceae	1		
Marsileaceae	3		
Najadaceae	2	1	50
Ophioglossaceae	2		
Orchidaceae	12	4	33
Orobanchaceae	1		
Paeoniaceae	4	1	25
Palmae	1		
Papaveraceae	3		
Pinaceae	1		
Plantaginaceae	2		
Plumbaginaceae	13		
Polygonaceae	3	1	33
Primulaceae	9	1	11
Ranunculaceae	17	3	18
Resedaceae	1		
Rosaceae	4	2	50
Rubiaceae	4	1	25
Salicaceae	1		
Santalaceae	1	1	100
Saxifragaceae	5	1	20
Scrophulariaceae	21	3	14
Solanaceae	1		
Thymelaeaceae	3	1	33
Ulmaceae	1		
Valerianaceae	1		
Violaceae	3		
Altogether	420	69	16%

Appendix 3 Results of the literature research

Author and publication year	Species name	Country	Type	Analysis method	Population size	Viability (individuals' parameters)	Extent of the population	Duration (years)
Carlsson and Callaghan (1990)	*Carex bigelowii*	Sweden	Autecological study	Basic	Density within plots	Yes	No	1984–1988
Janečková et al. (2006)	*Dactylorhiza majalis*	Czech	Autecological study	GLM	No	Yes	No	1999–2003
Pfeifer et al. (2006)	*Himantoglossum hircinum*	Germany	Monitoring	PVA	Total pop. size	Yes	No	1976–2001
Kullman (1983)	*Pinus sylvestris*	Sweden	Monitoring	Basic	Density within plots	Yes	No	1972–1981
Diaz-Almela et al. (2006)	*Posidonia oceanica*	Spain, Italy	Autecological study	GLM	No	Yes	No	1957–2004
Diemer (2002)	*Ranunculus glacialis*	Austria	Climate change	Basic	Density within plots	Yes	No	1986–1997
Arnold et al. (2005)	*Vitis vinifera subsp. silvestris*	France	Transplant experiment	Discriminant analysis	Total pop. size	Yes	Yes	1992–1997
Watkinson (1990)	*Vulpia fasciculata*	Wales	Autecological study	Basic	Density within plots	Yes	No	1974–1982
Garcia et al. (2002)	*Cypripedium calceolus, Borderea chouardii, Androsace pyrenaica, Petrocoptis pseudoviscosa, Petrocoptis montsicciana*	Spain	Monitoring	Basic	Total pop. size	Yes	Yes	1994–2000
Garcia (2003)	*Borderea chouardii*	Spain	Monitoring	PVA	Density within plots	Yes	No	1997–2002
Brzosko (2002)	*Cypripedium calceolus*	Poland	Autecological study	None	Density within plots	Yes	No	1989–1999
Bednorz (2003)	*Liparis loeselii*	Poland	Monitoring	None	Density within plots	Yes	No	1995–2002

Appendix 3 continued

Author and publication year	Species name	Country	Type	Analysis method	Population size	Viability (individuals' parameters)	Extent of the population	Duration (years)
Freville et al. (2004)	*Centaurea corymbosa*	France	Autecological study	PVA	Density within plots	Yes	No	1994–2001
Kirchner et al. (2006)	*Centaurea corymbosa*	France	Transplant experiment	Basic	No	No	No	10 years
Jäkäläniemi et al. (2006)	*Silene tatarica*	Finland	Autecological study	LTRE	No	Yes	No	1998–2003
Brys et al. (2004)	*Primula veris*	Belgium	Autecological study	GLM	Density within plots	Yes	No	1999–2003
Eriksson and Eriksson (2000)	*Plantago media*	Sweden	Autecological study	LTRE	Density within plots	Yes	No	1993–1997
Wells et al. (1998)	*Orchis morio*	England	Autecological study	Basic	Density within plots	Yes	No	1978–1995
Wells et al. (1998)	*Herminium monorchis*	England	Autecological study	Basic	Density within plots	Yes	No	1966–1995
Kull (1998)	*Cypripedium calceolus*	Estonia	Autecological study	Basic	Density within plots	Yes	Yes	Over 11 years
Svensson et al. (1993)	*Pinguicula alpina, Pinguicula villosa, Pinguicula vulgaris*	Sweden	Autecological study	Basic	Density within plots	Yes	No	1984–1991
Brzosko (2003)	*Platanthera bifolia*	Poland	Autecological study	Basic	Total pop. size	Yes	Yes	1996–2001
Gillman and Dodd (1998)	*Orchis morio*	England	Autecological study	Basic	Density within plots	Yes	No	1970–1995
Willems and Melser (1998)	*Coeloglossum viride*	Netherlands	Autecological study	Basic	Density within plots	Yes	No	1989–1995
Hutchings et al. (1998)	*Orchis militaris*	England	Autecological study	Basic	Total pop. size	Yes	Yes	1977–1995

Appendix 3 continued

Author and publication year	Species name	Country	Type	Analysis method	Population size	Viability (individuals' parameters)	Extent of the population	Duration (years)
Waite and Farrell (1998)	*Orchis militaris*	England	Autecological study	Basic	Total pop. size	Yes	Yes	1975–1991
Jones (1998)	*Liparis loeselii var. ovata*	Wales	Autecological study	Basic	Density within plots	Yes	Yes	1987–1995
Wheeler et al. (1998)	*Liparis loeselii*	England	Autecological study	Basic	Density within plots	Yes	Yes	1983–1990
Ramsay and Stewart (1998)	*Cypripedium calceolus*	England	Monitoring	None	Total pop. size	Yes	Yes	1970 s-
Hutchings (1987)	*Ophrys sphegodes*	England	Autecological study	Basic	Density within plots	Yes	Yes	1975–1984
Rose et al. (1998)	*Gentiana pneumonanthe*	England	Autecological study	GLM	Density within plots	Yes	No	1977–1991
Riba et al. (2002)	*Ramonda myconi*	Spain	Autecological study	Basic	Density within plots	Yes	No	1992–1999
Bengtsson (2000)	*Gypsophila fastigiata*	Sweden	Autecological study	Basic	Density within plots	Yes	No	1985–1998

References

Arnold C, Schnitzler A, Douard A, Peter R, Gillet F (2005) Is there a future for wild grapevine (*Vitis vinifera* subsp. *silvestris*) in the Rhine Valley? Biodivers Conserv 14:1507–1523. doi:10.1007/s10531-004-9789-9

Baillie J, Hilton-Taylor C, Stuart SN (2004) IUCN red list of threatened species: a global species assessment, international union for conservation of nature and natural resources red list, programme, World Conservation Union Species Survival, Commission, IUCN, The World Conservation Union

Bednorz L (2003) Population dynamics of *Liparis loeselii* (L) L. C. Rich. in the nature reserve 'Mielno'—some results from a 8 year study. EJPAU Biology 6(2)

Bengtsson K (2000) Long-term demographic variation in range-margin populations of *Gypsophila fastigiata*. Folia Geobot 35:143–160. doi:10.1007/BF02803093

BirdLife International (2004) Birds in the European Union: a status assessment. BirdLife International, Wageningen

Brys R, Jacquemyn H, Endels P, de Blust G, Hermy M (2004) The effects of grassland management on plant performance and demography in the perennial herb *Primula veris*. J Appl Ecol 41:1080–1091. doi:10.1111/j.0021-8901.2004.00981.x

Brzosko E (2002) Dynamics of island populations of *Cypripedium calceolus* in the Biebrza river valley (north-east Poland). Bot J Linn Soc 139:67–77. doi:10.1046/j.1095-8339.2002.00049.x

Brzosko E (2003) The dynamics of island populations of *Platanthera bifolia* in the Biebrza National Park (NE Poland). Ann Bot Fenn 40:243–253

Campbell SP, Clark JA, Crampton LH, Guerry AD, Hatch LT, Hosseini PR et al (2002) An assessment of monitoring efforts in endangered species recovery plans. Ecol Appl 12:674–681. doi:10.1890/1051-0761(2002)012[0674:AAOMEI]2.0.CO;2

Carlsson BÅ, Callaghan TV (1990) Effects of flowering on the shoot dynamics of *Carex bigelowii* along an altitudinal gradient in Swedish Lapland. J Ecol 78:152–165. doi:10.2307/2261042

de Heer M, Kapos V, ter Brink BJ (2005) Biodiversity trends in Europe: development and testing of a species trend indicator for evaluating progress towards the 2010 target. Philos Trans R Soc Lond, B 360:297–308. doi:10.1098/rstb.2004.1587

Diaz-Almela E, Marbá N, Álvarez E, Balestri E, Ruiz-Fernández JM, Duarte CM (2006) Patterns of seagrass (*Posidonia oceanica*) flowering in the Western Mediterranean. Mar Biol (Berl) 148:723–742. doi:10.1007/s00227-005-0127-x

Diemer M (2002) Population stasis in a high-elevation herbaceous plant under moderate climate warming. Basic Appl Ecol 3:77–83. doi:10.1078/1439-1791-00079

Dinerstein E et al (2007) The fate of wild tigers. Bioscience 57:508–514. doi:10.1641/B570608

Eriksson Å, Eriksson O (2000) Population dynamics of the perennial *Plantago media* in semi-natural grasslands. J Veg Sci 11:245–252. doi:10.2307/3236803

Freckleton RP, Watkinson AR (2002) Large-scale spatial dynamics of plants: metapopulations, regional ensembles and patchy populations. J Ecol 90:419–434. doi:10.1046/j.1365-2745.2002.00692.x

Freville H, Colas B, Riba M, Caswell H, Mignot A, Imbert E et al (2004) Spatial and temporal demographic variability in the endemic plant species *Centaurea corymbosa* (Asteraceae). Ecology 85:694–703. doi:10.1890/03-0119

Gaines WL, Harrod RJ, Lehmkuhl JF (1999) Monitoring biodiversity: quantification and interpretation. General technical report PNW-GTR-443, USA Department of Agriculture

Garcia MB (2003) Demographic viability of a relict population of the critically endangered plant *Borderea chouardii*. Conserv Biol 17:1672–1680. doi:10.1111/j.1523-1739.2003.00030.x

Garcia MB, Guzman D, Goñi D (2002) An evaluation of the status of five threatened plant species in the Pyrenees. Biol Conserv 103:151–161. doi:10.1016/S0006-3207(01)00113-6

Gillman MP, Dodd ME (1998) The variability of orchid population size. Bot J Linn Soc 126:65–74

Göteborg European Council–Presidency Conclusions (2001) Available at: http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressdata/en/ec/00200-r1.en1.pdf

Gregory RD, van Strien A, Vorisek P, Meyling AWG, Noble DG, Foppen RPB et al (2005) Developing indicators for European birds. Philos Trans R Soc B 360:269–288. doi:10.1098/rstb.2004.1602

Guralnick RP, Hill AW, Lane M (2007) Towards a collaborative, global infrastructure for biodiversity assessment. Ecol Lett 10:663–672. doi:10.1111/j.1461-0248.2007.01063.x

Hutchings MJ (1987) The population biology of the early spider orchid, *Ophrys sphegodes* mill. I. A demographic study from 1975 to 1984. J Ecol 75:711–727. doi:10.2307/2260201

Hutchings MJ, Mendoza A, Havers W (1998) Demographic properties of an outlier population of *Orchis militaris* L. (Orchidaceae) in England. Bot J Linn Soc 126:95–107

Inghe O (2001) The Swedish landscape monitoring programme: current status and prospects for the near future. In: Groom G, Reed T (eds) Strategic landscape monitoring for the Nordic countries (TemaNord 2001:523) Copenhagen, Nordic Council of Ministers, pp 61–67

Jacquemyn H, Brys R, Hermy M, Willems JH (2005) Are non-rewarding orchids more extinction-prone than rewarding species? An assessment using historical records from Belgium and the Netherlands. Biol Conserv 121:257–263. doi:10.1016/j.biocon.2004.05.002

Jäkäläniemi A, Tuomi J, Siikamäki P (2006) Conservation of species in dynamic landscapes: divergent fates of *Silene tatarica* populations in riparian habitats. Conserv Biol 20:844–852. doi:10.1111/j.1523-1739.2006.00348.x

Janečková P, Wotavová K, Schödelbauerová I, Jersáková J, Kindlmann P (2006) Relative effects of management and environmental conditions on performance and survival of populations of a terrestrial orchid, *Dactylorhiza majalis*. Biol Conserv 129:40–49. doi:10.1016/j.biocon.2005.09.045

Jones PS (1998) Aspects of the population biology of *Liparis loeselii* (L.) Rich. var. *ovata* Ridd. ex Godfery (Orchidaceae) in the dune slacks of South Wales, UK. Bot J Linn Soc 126:123–139

Kirchner F, Robert A, Colas B (2006) Modelling the dynamics of introduced populations in the narrow-endemic *Centaurea corymbosa*: a demo-genetic integration. J Appl Ecol 43:1011–1021. doi:10.1111/j.1365-2664.2006.01179.x

Kukk T, Kull T (eds) (2005) Atlas of the Estonian flora. Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences, Tartu

Kull T (1998) Fruit-set and recruitment in populations of *Cypripedium calceolus* L. in Estonia. Bot J Linn Soc 126:27–38

Kull T (1999) Estonian biodiversity strategy and action plan Keskkonnaministeerium, ÜRO Keskkonnakaitseprogramm (UNEP). EPMÜ Keskkonnakaitse Instituut, Tallinn-Tartu

Kull T, Hutchings MJ (2006) A comparative analysis of decline in the distribution ranges of orchid species in Estonia and the United Kingdom. Biol Conserv 129:31–39. doi:10.1016/j.biocon.2005.09.046

Kullman L (1983) Short-term population trends of isolated tree-limit stands of *Pinus sylvestris* L. in central Sweden. Arct Alp Res 15:369–382. doi:10.2307/1550832

Lindenmayer DB, Franklin JF (2002) Conserving forest biodiversity: a comprehensive multiscaled approach. Island Press, Washington, DC

Mace GM (2005) Biodiversity—an index of intactness. Nature 434:32–33. doi:10.1038/434032a

Niemelä J (2000) Biodiversity monitoring for decision-making. Ann Zool Fenn 37:307–317

Nimis PL, Scheidegger C, Wolseley PA (eds) (2002) Monitoring with lichens: monitoring lichens. NATO Science Series, IV Earth and Environmental Sciences, vol 7. Kluwer Academic Publishers, 408 pp

Noss RF (1990) Indicators for monitoring biodiversity: a hierarchical approach. Conserv Biol 4:355–364. doi:10.1111/j.1523-1739.1990.tb00309.x

Pereira HM, Cooper HD (2006) Towards the global monitoring of biodiversity change. Trends Ecol Evol 21:123–129. doi:10.1016/j.tree.2005.10.015

Pfeifer M, Wiegand K, Heinrich W, Jetschke G (2006) Long-term demographic fluctuations in an orchid species driven by weather: implications for conservation planning. J Appl Ecol 43:313–324. doi:10.1111/j.1365-2664.2006.01148.x

Plattner M, Birrer S, Weber D (2004) Data quality in monitoring plant species richness in Switzerland. Community Ecol 5(9):135–143. doi:10.1556/ComEc.5.2004.1.13

Preston CD, Pearman DA, Dines TD (2002) New Atlas of the British and Irish Flora. Oxford University Press, Oxford

Quayle JF, Ramsay LR (2005) Conservation status as a biodiversity trend indicator: recommendations from a decade of listing species at risk in British Columbia. Conserv Biol 19:1306–1311. doi:10.1111/j.1523-1739.2005.00083.x

Ramsay MM, Stewart J (1998) Re-establishment of the lady‘s slipper orchid (*Cypripedium calceolus* L.) in Britain. Bot J Linn Soc 126:173–181

Riba M, Picó FX, Mayol M (2002) Effects of regional climate and small-scale habitat quality on performance in the relict species *Ramonda myconi*. J Veg Sci 13:259–268. doi:10.1658/1100-9233(2002)013[0259:EORCAS]2.0.CO;2

Rich TCG, Woodruff ER (1996) Changes in the vascular plant floras of England and Scotland between 1930–1960 and 1987–1988: the BSBI monitoring scheme. Biol Conserv 75:217–229. doi:10.1016/0006-3207(95)00077-1

Rose RJ, Clarke RT, Chapman CB (1998) Individual variation and the effects of weather, age and flowering history on survival and flowering of the long-lived perennial *Gentiana pneumonanthe*. Ecography 21:317–326. doi:10.1111/j.1600-0587.1998.tb00569.x

Ryttari T (1997) Monitoring of threatened vascular plants in Finland: development of methodology. In: Kanerva T, Kemppainen E (eds) Conservation, monitoring and management of threatened vascular plants and their habitats. Vantaa

Ryttäri T, Kukk Ü, Kull T, Jäkäläniemi A, Reitalu M (eds) (2003) Monitoring of threatened vascular plants in Estonia and Finland—methods and experiences. The Finnish Environment 659, Helsinki

Sala OE, van Vuuren DP, Pereira P, Lodge D, Alder J, Cumming G et al (2006) Biodiversity across scenarios. In: Carpenter S, Pingali P (eds) Ecosystems and human well-being: scenarios. Island Press, Washington, DC

Sammul M, Kull T, Lanno K, Otsus M, Mägi M, Kana S (2008) Habitat preferences and distribution characteristics are indicative of species long-term persistence in the Estonian flora. Biodivers Conserv (this volume) (accepted for publication)

Southwood TRE, Henderson PA, Woiwod IP (2003) Stability and change over 67 years - the community of *Heteroptera* as caught in a light-trap at Rothamsted, UK. Eur J Entomol 100:557–561

Svensson BM, Carlsson BÅ, Karlsson PS, Nordell KO (1993) Comparative long-term demography of three species of *Pinguicula*. J Ecol 81:635–645. doi:10.2307/2261662

Waite S, Farrell L (1998) Population biology of the rare military orchid (*Orchis militaris* L.) at an established site in Suffolk, England. Bot J Linn Soc 126:109–121

Watkinson AR (1990) The population dynamics of *Vulpia fasciculata*: a nine-year study. J Ecol 78:196–209. doi:10.2307/2261045

Weaver JC (1995) Indicator species and scale of observation. Conserv Biol 9:939–942. doi: 10.1046/j.1523-1739.1995.09040939.x

Wells TCE, Rothery P, Cox R, Bamford S (1998) Flowering dynamics of *Orchis morio* L. and *Herminium monorchis* (L.) R.Br. at two sites in eastern England. Bot J Linn Soc 126:39–48

Wheeler BD, Lambley PW, Geeson J (1998) *Liparis loeselii* (L.) Rich. in eastern England: constraints on distribution and population development. Bot J Linn Soc 126:141–158

Willems JH, Melser C (1998) Population dynamics and life-history of *Coeloglossum viride* (L.) Hartm: an endangered orchid species in The Netherlands. Bot J Linn Soc 126:83–93