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Accurate determination of vegetational change in meadows by successive point quadrat analysis

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Abstract

The point quadrat method can be used for determination of vegetational change in meadows of great species diversity. An appropriate sampling technique is described comprehending an apparatus of high rigidity and a shelter to keep off wind and rain. Sample size related to sampling time expense affects the number of species recorded and methodical error which is empirically determined by repetitive sampling. A setup of fixed points leads to higher accuracy than random sampling. When methodical error is quantitatively known, significant vegetational change can be detected by sampling at successive times.

For fluctuation studies of plant populations in meadows the point quadrat technique should be preferred to visual estimates of plant cover because of its higher accuracy.

Abbreviations: f = frequency, s = standard deviation, S_r = variation coefficient, DWLS = distance weighed least squares

Nomenclature: for vascular plants: Binz & Heitz (1986), Schul- und Exkursionsflora für die Schweiz, Schwabe, Basel; for syntaxa: Ellenberg (1978), Vegetation Mitteleuropas mit den Alpen, Ulmer, Stuttgart.

Introduction

Vegetational change can be determined by analysis of the same area at successive times. However, before results may be interpreted, the accuracy of the measuring technique has to be quantified as has recently been done for visual estimates of plant cover (Kennedy & Addison 1987; Sykes *et al.* 1983). Because error values, proved by these studies, are too high, visual estimates are not suitable for the analysis of year-to- year changes in meadows and particularly not in meadows of high structural complexity and species density. Also frequency determination using small quadrats (Watt 1960) and charting of plant locations (Lieth & Ellenberg 1958) do not seem to be a practicable method to work with, in a meadow of this kind.

In a long-term experiment to investigate the early processes of secondary succession and fluctuations of plant populations, the point quadrat method was selected because it is regarded as

'one of the most trustworthy and most nearly objective methods' (Goodall 1952). This quantitative method has been widely recommended for measurements of cover (e.g. Mueller-Dombois & Ellenberg 1974; Schmidt 1974; Greig-Smith 1983; Knapp 1983, 1984), which is the most suitable criterion for estimating changes (Watt 1960). Some critical remarks on the use of the point quadrat method for permanent plot studies are concerned with sampling expense, which might be too high for some purposes (Pfadenhauer *et al.* 1986); effects by 'seasonal changes' (Krüsi 1978) and 'doubtful reproducibility' (Pfadenhauer *et al.* 1986) however are not general arguments against the use of the method for permanent plot studies.

For many purposes a random distribution of points is proposed (Goodall 1952; Knapp 1983; Everson *et al.* 1990). This allows computing errors from statistical principles. In detecting vegetational change however the same point locations for subsequent remeasurements have to be preferred to new random allocation for economical reasons (see recommendations by Goodall 1952 and Radcliffe & Mountier 1964). Even if sampling is done at fixed points, repetitive analysis of the same area does not yield exactly the same results (Levy & Madden 1933). Returning to identical points each time requires an impracticable precision of location. What is actually done, as Radcliffe & Mountier (1964) stated, is returning to the same small areas and resampling these. Unlike new random allocation each time this achieves a reduction in the sampling error for comparisons in time. As there is no means of estimating the variance of a single set of systematic samples (Greig-Smith 1983), an empirical determination using repetitive sets of samples was necessary.

The objectives of this study were to describe a practicable point quadrat technique for meadows based on fixed points, as used in a nearby long-term study, to determine its sampling error and to relate this error to sample size. Considering accuracy, this technique will be compared to random point quadrat sampling (Goodall 1952) and visual estimates of plant cover (Kennedy & Addison 1987; Sykes *et al.* 1983).

Study site

The study site is located close to the footpath leading from Prugiasco to the old church of San Carlo di Negrentino in the southern alpine Valle di Blenio (Ticino, Switzerland). Compared to close Insubrian climate type stations this valley gets somewhat smaller amounts of annual rainfall (1300 mm) and summer dry periods can sometimes be drastic. At an elevation of 820 m the study site is embedded in a south facing slope of up to 20°. For at least 50 years as elderly inhabitants of the village remember, the meadows of Negrentino have been well cared for by local farmers who cut the grass twice a year by end of June and in fall. The species composition of the study site reflects features of *Mesobromion* communities but as the soils are moderately acid, pH = 5.4 (top of soil sample, measured in water), deeply weathered (thickness of A- and B- horizons: 105 cm) and of a rather low nutrient content, *Festuca tenuifolia* and *Danthonia decumbens*, both indicating poor soils, are also quite abundant. Nevertheless some species of a slightly manured *Trisetion* community situated close by are also present. The species diversity of the meadow is very high and most of the species appeared to be quite evenly distributed. Places of up to 50 vascular plant species per square meter can be found.

Methods

Sampling technique

A preliminary test setup using a rather simple metal frame as suggested by Mueller-Dombois & Ellenberg (1974) yielded structural features of the meadow in June. The needle used together with this frame measured 3 mm in diameter and was long enough to contact even the tallest plants possible (1 m). A data set of 100 regularly spaced points within a test area of one square meter showed that most contacts (97%) happened at a height of less than 40 cm (Fig. 1).

A long wobbling needle rendering all but no

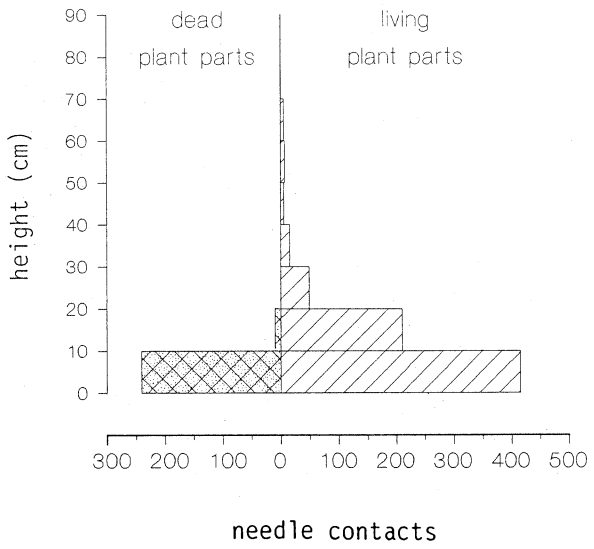

Fig. 1. Above ground distribution of all needle contacts with dead and living plant parts showing the structural character of the meadow in mid June (preliminary setup, 100 points).

unequivocal contacts with fully developped plants moved by disturbing winds and a high risk of rainfall during longer periods of data collection pointed out the limits of this setup. The rigidity of frame and needle had to be improved (see Radcliffe & Mountier 1964) and a shelter for weather protection had to be constructed. Higher rigidity of the needle was achieved by shortening its length to about 60 cm. From Figure 1 was concluded that a sampling height of 40–50 cm is still appropriate. Since the density of culms of tall grasses may fluctuate in time, it has to be sampled by another technique to get an idea of its effect on results in time. A light greenhouse with a plastic covering the roof and three of four sides was constructed to protect an area of 200 × 220 cm^2 from wind and rain during field analysis.

The improved apparatus used in this study is shown in Figure 2. It consists of two tripods supporting a linking bar carrying a sort of sled to which a pointed steel needle, 3 mm in diameter, is attached by two guiding holes. A water-level is fixed upon the linking bar to guarantee a similar needle position at subsequent remeasurements.

As needle-foliage contacts within the thicket of the lowest 15 cm may be hidden a toothpick is required to move away covering plant parts. Hits

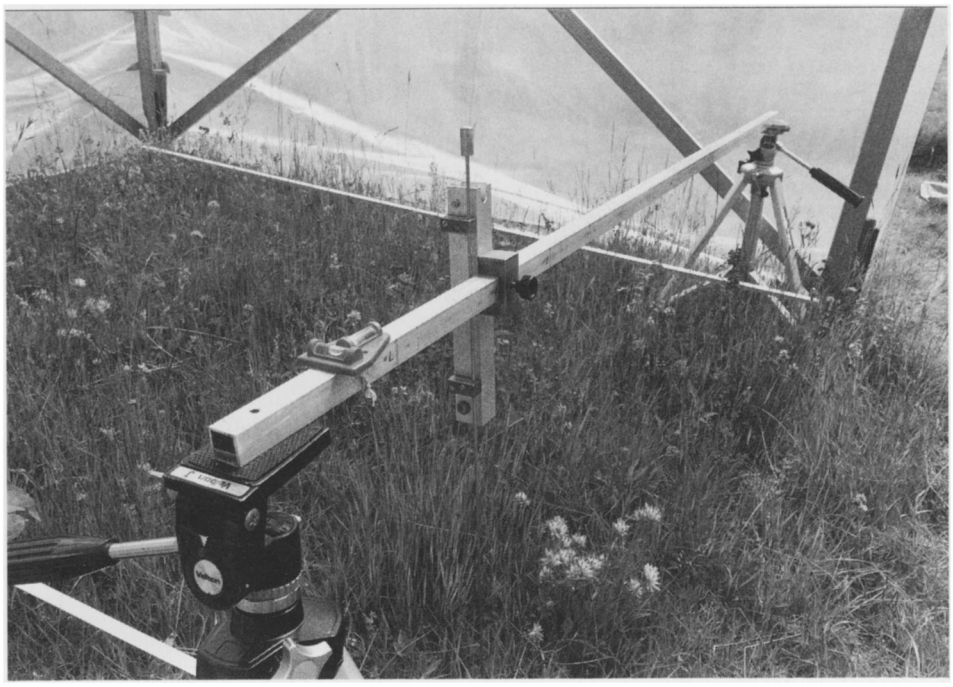

Fig. 2. Point quadrat apparatus used for the present study.

are recorded if any part of the needle touches the foliage. Just recording what the point of the needle strikes on its way down to get precise cover data (see Radcliffe & Mountier 1964; Poissonet & Poissonet 1969: 'méthode de référence') appeared to be impracticable, because simultaneously handling the needle and operating the toothpick to get a sight of the needle point as it is moving downwards is an inconvenient task to do for a long time. Overestimation of species cover by effect of a finite needle diameter (see Goodall 1952) is not a problem anyhow when changes in time are the aim and the same equipment is used at successive remeasurements throughout the study.

Experimental design

For the present study on accuracy of the method an area of 200 × 220 cm^2 was selected close to 18 experimental plots of the same kind from where longer term data is being collected. Within this area a study plot of 110 × 160 cm^2 was sampled between 25 May and 4 June 1989, when the meadow had reached its flowering optimum. After a visual relevé (relevé method, see Mueller-Dombois & Ellenberg 1974) had been carefully performed without touching the vegetation, point frequency records (sensu Goodall 1952) of 176 points, consisting of 16 rows and 11 columns at regular distances of 10 cm, were registered in each row ten times, thus successively collecting tenfold serial data of each row. Special care was given to prevent vegetation disarranging by the observer.

Using the water-level the apparatus was adjusted with the help of the needle and marks drawn at 10 cm intervals on two laterally fixed metal bars serving as guide-lines. For every first point of a row the position of the needle coming down to the ground was marked by sticking a toothpick into the ground. After one series of 11 points had been accomplished by the first observer the apparatus was removed and then readjusted for a repetitive series, which was carried out by the second observer, the third series was done by the first observer again, and so on. At every first point of the nine following series the position of the needle was compared to the position of the toothpick in order to get an idea of the area such a 'point' actually represents.

Evaluation of samples and sub-samples

In order to study the effect of sample size from the total sample of 176 points at regular distances of 10 cm several sub-samples of different point number and point spacing were taken at regular distances as shown in Figure 3.

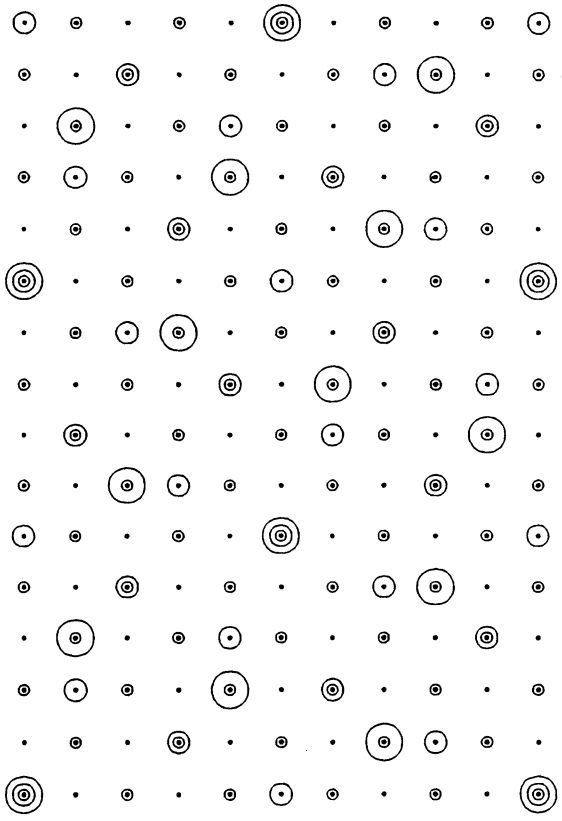

Fig. 3. Study plot showing the total sample (a) and three sub-samples (b), (c), (d) of variable size (number of regularly spaced points).
· a) 176 points (10 cm apart)
◦ b) 88 points (14.3 cm apart)
o c) 36 points (22.4 cm apart)
O d) 18 points (31.6 cm apart)

Error analysis

In order to get a model of the relationship between frequency and error for the sampling approach based on fixed points, the graphs of all species *f-s*-values showed in Figure 5A and Figure 6 were 'averaged' by a curve produced by a method of weighted quadratic multiple regression (DWLS-smoothing) using an algorithm due to McLain (1974); see Wilkinson, Leland. SYGRAPH: The System for Graphics. Evanston, IL: SYSTAT, Inc. 1990.

Results

Time expense, sample size and species diversity

Using an experimental design as presented in this study one plot of 176 points can be sampled within four to five hours when two observers alternately sample one row requiring 15 to 20 min each. This is two to three times as much time compared to what is needed for a visual relevé carefully performed by one person.

When point quadrat sampling is done at regular spaces, sample size, equal to number of points sampled, is a function of point density and area size. Sampling at variable point density (regular spacing) on the same area (1.76 m^2) affects the number of species recorded as shown in Figure 4A. The median of ten repetitive samples was 39 species using 176 points at spaces of 10 cm, thus 78% of the total number of 50 species present on the plot were recorded. More species (92%) were discovered by using the method of visual relevé. A huge number of narrowly spaced points and an immense time expense would be necessary to record the whole species diversity.

When the same sample size is used on a larger area (17.6 m^2) within the meadow fulfilling the homogeneity requirements (Mueller-Dombois & Ellenberg 1974) an increased number of species is recorded (see Figure 4B). Considering percentage of total number of species present on an area however, higher point density leads to increased

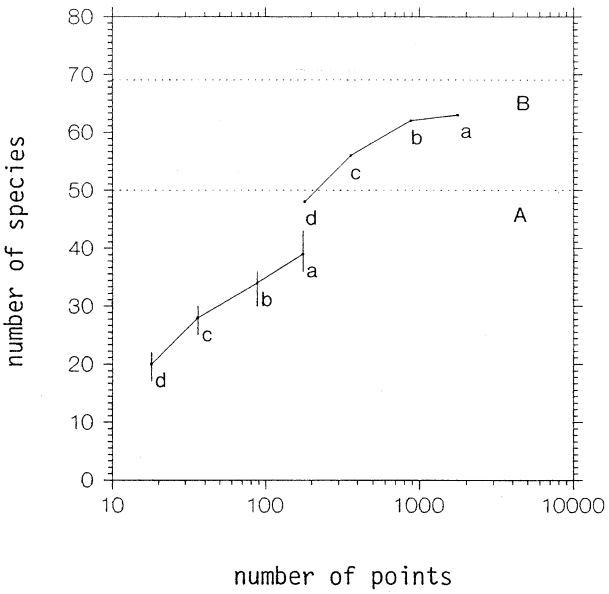

Fig. 4. Relation of samples size and number of species recorded, (A) using samples a–d of different point density (see Fig. 3) on the study plot (1.76 m^2, 50 species totally present), the line links medians of ten repetitive records, bars show maxima and minima, (B) using samples A–D of different point density on the total area of the study plot and nine similar experimental plots close by (17.6 m^2, 69 species totally present), the line links single records.

values, thus larger values are obtained when sampling is done on a smaller area using narrower spacing.

Methodical error

The points sampled at repetitive times scattered within areas of a few square centimeters. The majority of repetitive points, six out of ten, were less than 1.75 cm apart. Ten repetitive frequency values based on the total sample (see Figure 3a) are displayed in Table 1: Species showing highest frequency values (f) showed high standard deviation (s) but lowest variation coefficients (S_r) and vice versa. Highly frequent species are therefore more accurately recorded than lowly frequent ones. As an expression of sampling error the standard deviation of every species in Table 1 is plotted against the frequency mean (Fig. 5A). A logarithmic scale is used to get a better display of the

Table 1. Ten repetitive point frequency results [%] based on the total sample of 176 points in one study plot and statistical scores (mean, standard deviation s and variation coefficient s_r).

Species	Repetitive point quadrat samples										Mean	s	s_r
	1	2	3	4	5	6	7	8	9	10			
Festuca tenuifolia	55.1	50.6	50.0	46.0	42.6	54.5	49.4	47.2	53.4	51.1	50.0	3.9	7.9
Bromus erectus	36.9	42.0	36.9	40.3	39.2	38.1	35.2	36.4	38.6	32.4	37.6	2.7	7.2
Carex verna	32.4	35.8	30.1	36.4	33.5	31.8	35.8	35.8	35.8	35.8	34.3	2.2	6.4
Festuca rubra ssp. *rubra*	35.2	34.1	39.2	35.8	32.4	33.5	31.8	33.5	25.6	38.1	33.9	3.8	11.1
Brachypodium pinnatum	35.8	35.8	21.0	32.4	29.0	32.4	24.4	30.1	29.0	34.7	30.5	4.9	15.9
Agrostis tenuis	24.4	26.7	23.3	22.2	21.0	21.0	22.7	27.3	18.8	26.7	23.4	2.8	12.2
Anthoxoanthum odoratum s.str.	15.9	18.8	10.2	17.6	18.2	18.8	11.9	18.8	12.5	17.0	16.0	3.2	20.2
Plantago lanceolata	17.0	13.1	14.2	10.2	12.5	13.1	13.1	12.5	11.9	12.5	13.0	1.7	13.4
Thalictrum minus	15.3	10.2	9.7	8.0	8.5	10.8	10.8	9.1	9.7	10.8	10.3	2.0	19.7
Dactylis glomerata	8.5	12.5	7.4	6.3	8.5	8.5	6.3	8.5	9.1	8.5	8.4	1.8	20.8
Luzula campestris	7.4	8.0	8.0	5.1	7.4	8.5	8.0	10.2	10.2	9.7	8.2	1.5	18.7
Trifolium montanum	11.4	5.7	8.5	8.5	10.2	7.4	6.8	6.3	4.0	6.3	7.5	2.2	29.4
Danthonia decumbens	7.4	4.5	7.4	9.7	3.4	4.5	5.7	5.1	4.5	9.1	6.1	2.1	34.6
Sanguisorba minor	5.7	9.1	4.5	6.3	5.1	4.5	5.7	4.0	6.3	5.7	5.7	1.4	24.9
Primula veris s.l.	4.0	5.7	5.1	5.1	4.5	6.3	2.8	4.0	5.1	5.7	4.8	1.0	20.9
Veronica spicata	3.4	2.8	5.1	4.5	4.0	5.7	4.5	4.5	5.7	4.0	4.4	0.9	20.8
Briza media	1.7	4.0	4.5	5.1	5.1	2.8	2.3	4.0	2.3	5.1	3.7	1.3	35.7
Campanula rotundifolia	4.0	2.3	2.8	3.4	3.4	4.5	5.7	3.4	3.4	1.7	3.5	1.1	32.3
Trifolium repens	5.1	3.4	2.8	2.3	3.4	2.3	3.4	5.1	3.4	2.3	3.4	1.1	31.4
Salvia pratensis	2.8	2.8	1.7	3.4	4.5	2.8	2.3	2.8	2.3	2.3	2.8	0.8	28.0
Leontodon hispidus s.l.	2.3	3.4	1.7	2.3	2.3	2.3	3.4	2.8	2.8	2.8	2.6	0.5	21.0
Lotus corniculatus s.str.	1.7	1.7	2.8	2.8	3.4	3.4	2.8	2.3	2.3	2.3	2.6	0.6	24.0
Ranunculus bulbosus	3.4	3.4	2.8	1.7	1.7	0.6	2.3	3.4	2.3	4.0	2.6	1.0	40.9
Leucanthemum vulgare s.str.	3.4	2.3	1.7	1.7	2.8	1.7	1.7	0.6	1.7	2.3	2.0	0.8	38.7
Potentilla pusilla	2.3	2.3	1.7	1.7	1.7	1.7	1.7	2.3	1.7	1.7	1.9	0.3	14.6
Prunella vulgaris	1.7	1.7	2.3	1.1	1.1	2.3	1.7	1.7	1.7	2.3	1.8	0.4	23.8
Phyteuma betonicifolium	2.8	2.8	1.7	1.7	2.8	2.3	1.7	0.6	0.6	1.1	1.8	0.9	48.4
Trifolium pratense ssp. *pratense*	1.1	2.3	2.3	1.7	2.8	1.1	1.1	1.7	1.7	0.6	1.6	0.7	41.3
Achillea millefolium s.l.	1.1	0.6	1.7	1.7	1.7	1.7	2.3	1.1	0.6	2.8	1.5	0.7	46.4
Viola hirta	0.6	0.6	1.7	1.7	·	1.1	2.3	0.6	2.3	2.3	1.3	0.8	65.0
Avenula pubescens	1.1	0.6	1.1	0.6	1.1	1.7	1.1	1.1	1.1	2.3	1.2	0.5	41.7
Scabiosa columbaria	1.1	0.6	0.6	0.6	1.7	1.1	1.1	1.1	1.1	1.1	1.0	0.4	35.1
Potentilla erecta	1.7	1.1	1.1	·	0.6	1.1	1.1	1.1	1.1	0.6	1.0	0.5	48.4
Paradisea liliastrum	0.6	1.7	1.7	0.6	·	1.7	0.6	0.6	1.1	·	0.9	0.7	78.6
Silene nutans	2.3	0.6	0.6	1.7	·	0.6	1.1	1.1	·	·	0.8	0.8	96.4
Holcus lanatus	0.6	0.6	0.6	·	1.1	1.7	0.6	0.6	0.6	0.6	0.7	0.4	65.7
Anthyllis vulneraria	1.1	0.6	0.6	0.6	·	0.6	0.6	0.6	·	0.6	0.5	0.3	63.1
Thymus pulegioides	0.6	1.7	0.6	0.6	0.6	·	·	·	·	0.6	0.5	0.5	114.9
Botrychium lunaria	0.6	0.6	0.6	0.6	·	0.6	·	0.6	0.6	·	0.4	0.3	69.0
Trisetum flavescens	·	1.1	0.6	·	1.1	0.6	·	·	·	·	0.3	0.5	140.5
Koeleria macrantha	0.6	0.6	·	·	0.6	·	1.1	·	·	·	0.3	0.4	141.4
Arabis ciliata	0.6	·	·	·	·	·	0.6	0.6	0.6	·	0.2	0.3	129.1
Rumex acetosa	·	·	·	·	·	·	·	0.6	0.6	0.6	0.2	0.3	161.0
Ajuga reptans	·	0.6	·	·	·	·	·	·	0.6	·	0.1	0.2	210.8
Rhinanthus alectorolophus	·	0.6	·	0.6	·	·	·	·	·	·	0.1	0.2	210.8
Carex pallescens	·	·	·	·	·	·	·	0.6	·	·	0.1	0.2	316.2
Contacts with not identified species	2.3	·	·	·	·	·	0.6	1.1	0.6	0.6			

No records of the following species present on the study plot: *Carex ornithopoda, Clinopodium vulgare, Orchis morio, Populus tremula*

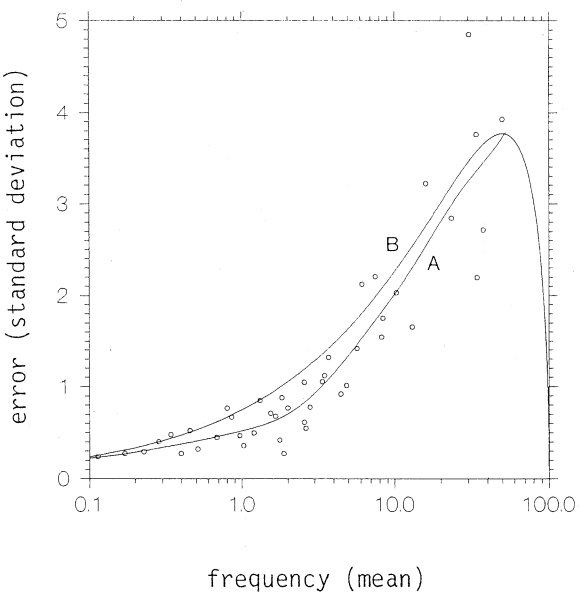

Fig. 5. Relation of frequency (mean) and error (standard deviation) using a sample size of $n = 176$ points and two different approches: (A) empiric values of species displayed in Table 1, based on ten repetitive records at fixed points, smoothed using DWLS. (B) theoretical, based on Goodalls equation for random points.

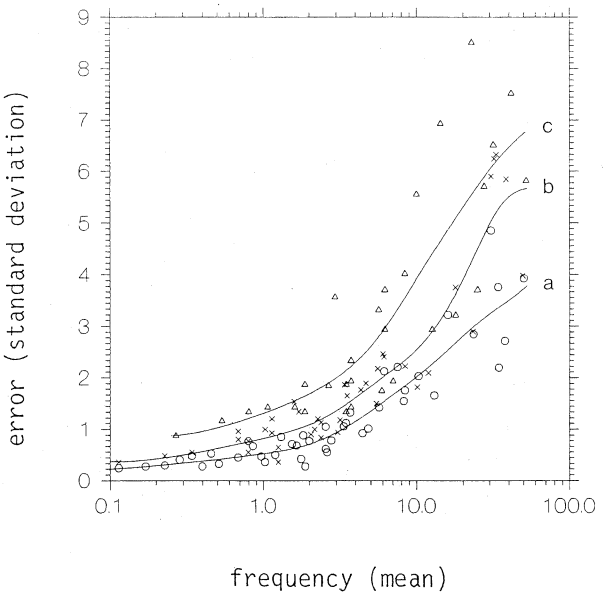

Fig. 6. Relation of frequency (mean of ten repetitive records) and error (standard deviation) using different sample sizes of a = 176 (o), b = 88 (×) and c = 36 (△) points. The species values, derived from Table 1 (sample a) and analogous tables (samples b and c), are smoothed using DWLS.

many low-frequent species. Even though distribution of the 46 species can not clearly be related to different morphological characters using our relatively small data set (ten repetitive samples) some morphological effect on sampling error is evident: Species showing relatively small errors are either dwarf plants, as *Carex verna*, *Luzula campestris*, *Veronica spicata* and *Potentilla pusilla*, or have relatively large leaves close to the ground surface, as *Plantago lanceolata*, *Primula veris* s.l., *Leontodon hispidus* s.l. and *Prunella vulgaris*, whereas species showing relatively large errors have easily movable graminaceous leaves as *Brachypodium pinnatum*, *Danthonia decumbens* and *Trisetum flavescens* or a centre of gravity relatively far from the ground surface as *Anthoxanthum odoratum* s.str., *Trifolium montanum* and *Silene nutans*. The standard deviations of *Festuca tenuifolia* and *F. rubra* ssp. *rubra* might have been raised very little by misidentification of some young leaves. Scattering may be explained as a complex of effects of inexact needle location and minor vegetation disarranging between repetitive samples, both differently influenced by plant architecture and plant distribution pattern, and observer mistakes.

The graphs obtained by DWLS-smoothing (Fig. 5A and Fig. 6) may be used for statistical error calculations assuming normal distribution of repetitive species values, however, when error calculations are based on such an 'averaging' the above-mentioned probable morphological effects must also be taken into consideration. The sampling errors of species frequency results are also influenced by sample size. Figure 6 shows graphs analogous to Figure 5A using different sample sizes (see Fig. 3a–c).

Methodical error: fixed points versus random points

Repetitive results based on randomly distributed points also show variability. Goodall (1952) introduced the following equation to compute the standard deviation of frequency values (f) ob-

tained by use of n points:

$$s = \sqrt{f(1-f)/n}$$

The s-f-graphs for both sampling approaches (Fig. 5) lead to the conclusion that repetitive results show a smaller variability based on fixed points than based on random points, however considering morphological effects this conclusion concerns mainly plants with a gravity centre close to ground surface.

Conclusion

Vegetational change and fluctuations of plant populations can be analysed by use of point quadrat technique at successive times. A change in species frequency values within an interval t_1–t_2 may be considered significant when the difference between the frequency values $f(t_1)$, $f(t_2)$ exceeds confidence limits of methodical error which can be determined based on the s-f-model (Fig. 5A). Presuming confidence limits of 95% methodical error ($e_{.95}$) can be calculated as follows:

$$e_{.95} = 1.96 \cdot \sqrt{s_1^2 + s_2^2}$$

A change in species frequency is significant when:

$$e_{.95} < |f(t_2) - f(t_1)|$$

As an example frequency values of three successive years of *Brachypodium pinnatum* from two differently managed experimental plots close by are shown in Figure 7. Errors intervals are derived from DWLS-smoothed standard deviations (Fig. 5A): $s(a_{1988}) = 3.25$, $s(a_{1989}) = 2.84$, $s(a_{1990}) = 2.94$, $s(b_{1988}) = 3.38$, $s(b_{1989}) = 3.71$, $s(b_{1990}) = 3.71$.

Difference of frequency values, methodical error and significance of change are calculated using the above-mentioned equations:

$f(a_{1989}) - f(a_{1988}) = -9.6$	$e_{95} = 8.46$	decrease s.
$f(a_{1990}) - f(a_{1989}) = 1.1$	$e_{95} = 8.01$	increase n.s.
$f(b_{1989}) - f(b_{1988}) = 15.9$	$e_{95} = 9.84$	increase s.
$f(b_{1990}) - f(b_{1989}) = 13.1$	$e_{95} = 10.28$	increase s.

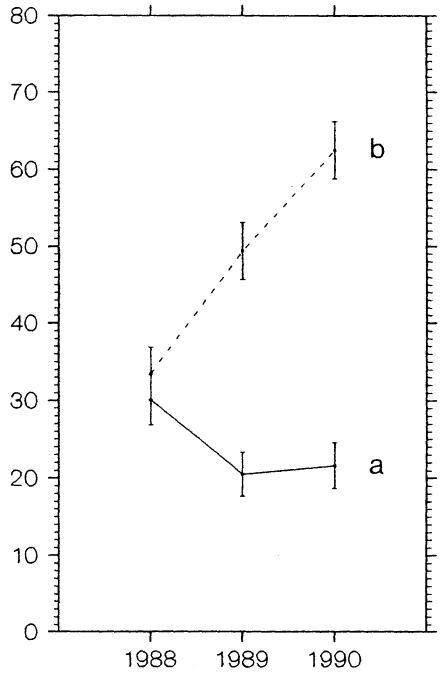

Fig. 7. Frequency change of *Brachypodium pinnatum* on two plots a (line) and b (dots) in three successive years 1988–1990, (a) traditionally managed, (b) abandoned since 1988; bars showing standard error (s) of the measuring technique. Significant increase happened on plot b, whereas significant decrease took place on plot a within the first and insignificant increase within the second time interval (see text).

Discussion

The expense for sampling was found to be much more time consuming than indicated by Mueller-Dombois & Ellenberg (1974). In meadows of high structural complexity and species richness careful work requires much more time.

Consistent with the recommendations of Goodall (1952) and Radcliffe & Mountier (1964) methodical error was found to be smaller when reproduced point quadrat sampling is done at fixed points. Therefore the random approach, suitable only for species covering more than 10% (Knapp 1983: 'cover' roughly corresponding to 'point frequency'), is considered less cost-effective. Random resampling for monitoring plant species composition as recently proposed by Everson *et al.* (1990) can not be recommended. The validity of a general notion (Knapp 1984)

considering a random distribution of needles to be more appropriate than regular distribution must be restricted to plotless frequency assessment at one given moment. It can not be accepted for vegetational change studies in time.

When fixed points are used for such studies significant change can be detected even for species showing frequency values less than 5% (applying a sample size of only 176 points). If higher accuracy is requested by particular goals of a study, increasing the sample size by narrower point spacing is still possible. These results refer to the relatively small area of the study plot. In order to get a representative sample of a large meadow or a statistically sound result of changes in time, several study plots have to be monitored. Although this eventually leads to an increased time expense comparable to plotless random sampling, there is still a crucial advantage in systematic sampling: it makes detection of small scale spatial differences possible.

Reasonable error estimation values can be calculated for regular point quadrat sampling designs using Goodalls equation valid for randomly distributed points. Precise error results however have to be determined empirically and this is much more time consuming.

Growth form, distribution and visibility affect personal errors made by the observer using visual estimations of plant cover (Kennedy & Addison 1987). The same authors found that species with low cover values showed large *relative* error values. This is not opposed to estimations of Sykes *et al.* (1983) who referred to *absolute* error values, stating that cover estimates were likely to be most in error in the central 50% region and least in error at the two extremes, near 0% and 100%. Quantifications by Sykes *et al.* (1983), derived from species covering more than 10%, resulted in absolute error intervals of ± 6–18% cover (95%-confidence intervals) for estimates repeated by a single observer a few days later and approximately ± 12–24% cover when different observers repeat estimates. Error intervals using point quadrat method are considerably smaller as shown in this study. The use of 176 fixed points led to 95%-confidence error intervals of approximately ± 1.3–7.2% frequency for species values between 2–50% frequency.

Because of this crucial difference in accuracy the point quadrat method is appropriate for meadows where observer errors are particularly high. It should be preferred when the determination of year-to-year fluctuations of plant populations is the aim of a study. For simultaneous monitoring of rare species populations however other methods have to be combined with point quadrat analysis.

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