A Simplified Strategy for Evaluating Change in Plant Communities

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Abstract: *Implementation of monitoring programmes in ecological impact assessment frequently requires rapid, cost-effective surveys of vegetation along a time scale that varies according to the nature of the studies being carried out. When time constraints are restrictive such surveys may be qualitative and therefore highly dependent on the experience and competence of the observer. Reduction of subjectivity may be achieved by quantifying observation, an approach that would however increase time constraints and reduce cost-effectiveness. The sampling and assessment strategy being proposed here is a semi-quantitative approach to determination of relative abundance of species. It retains the low effort-demand of qualitative technique whilst introducing a flexible quantitative aspect that may be incrementally adjusted towards specific requirements.*

Keywords: *Plant communities, monitoring, ecological impact assessment, sampling strategies, community dynamics.*

Introduction

Longitudinal monitoring of plant communities, such as that associated with some forms of Ecological Impact Assessment, is generally carried out in response to extraordinary environmental change (usually anthropogenic) under the assumption that such change would generate a shift in community composition and dynamics. The role of environmental monitoring is to establish the magnitude and direction of such changes in plant communities.

Detection of such change may not be simple as plant communities are in a constant state of flux even when underlying environmental controls would be characterised by relative stability. Three basic scales of natural community change are evident in the absence of extraordinary environmental change:

(1) Intra-annual change: shifts in community composition caused by seasonal change. This is mainly a consequence of predictable cycles of presence and absence of herbaceous annual species in response to seasonal cycles in environmental factors.

(2) Inter-annual change: shifts in community composition from year to year correlated with fluctuations in the population sizes of herbaceous annual species. Inter-annual dynamics of these species are usually unpredictable and related to small-scale environmental stochasticity.
(3) Longer-term change: changes in the high-biomass framework of perennial species (usually trees or shrubs) as a consequence of autogenic ecological succession.

Detection of community shifts that are directly attributable to extraordinary change (post-disturbance variation) is seldom simple. Such changes are superimposed on autogenic background change (pre-disturbance variation) and separation of the two processes is dependent on the quantity and quality of pre-existing baseline data. With or without baseline data, the social and planning constraints within which monitoring programmes operate necessitate regular, rapid and cost-effective characterisation of plant communities over timescales that are relatively short in ecological terms.

Estimates of community change are generally obtained utilising either of two principal approaches:

(1) **Quantitative methods:** based on collection of empirical data pertaining to the abundance (absolute and/or relative) of selected species. Such methods provide objectively-acquired results that may be reproduced by independent observers. These strategies are labour-intensive and may require considerable investment of effort and human resources.
(2) **Qualitative methods:** based on the subjective, non-empirical assessment of the abundance of individual species through a visual survey. Such methods are convenient in that effort-demand is comparatively low. However, results obtained through such strategies may be irreproducible and are highly dependent on the experience and bias of the individual observer.

The sampling and assessment strategy being proposed here is a semi-quantitative approach to determination of relative abundance of species. It retains the low effort-demand of qualitative technique whilst introducing a flexible quantitative aspect that may be incrementally adjusted towards specific requirements.

Preliminary work

(1) The area of study is subdivided into a number of permanent plots using a grid superimposed on a survey sheet representing the area. The resolution of this grid (i.e. the size of each plot) is dependent on the vegetation life-forms being sampled and on the observer's required level of precision. Finer resolution would generate results of higher quality but would also be more effort-intensive, more time-consuming and therefore more costly. Decisions on cost-effectiveness of the sampling programme would be dependent on the observer and would form an integral part of initial planning.

(2) Each plot would be further subdivided into a number of subplots using a secondary grid that is overlain over each plot. The resolution of subplots is once again subject to considerations of cost-effectiveness. Such considerations notwithstanding, the dimensions of subplots are generally expected to be in the order of 5m square ($25m^2$) to 20m square ($400m^2$). The location of each subplot in the field would be determined using GPS and subsequently indicated by a permanent physical indicator in order to facilitate recovery of position.

General sampling strategy

(1) The empirical portion of the survey is preceded by a general census of the macrophytic vegetation present in the entire area of study. No attempt at quantification should be carried out at this stage since such a step would follow later.

(2) A number of subplots within each plot are selected for sampling using a random-number generator. The number of subplots selected within each plot may be determined through the construction of species-area curves for each plot as described in Kent & Coker (1999). Such selection of subplots is carried out for each plot in the area of study.

(3) A list of plant species present in each selected subplot is compiled. Such a list would only record presence or absence of species and no further quantification would be carried out at the subplot level.

(4) The procedure is repeated for all selected subplots in every plot.

Treatment of results

The presence/absence data collected in the field are subsequently converted into frequencies of occurrence for each species within each plot and across the entire area of study. An Index of Abundance (IoA) for each species may then be derived from the frequency data. A suggested scheme for the determination of such an index is given below:

Index of Abundance	Criterion
10	Present in 90%–100% of subplots
9	Present in 80%–89% of subplots
8	Present in 70%–79% of subplots
7	Present in 60%–69% of subplots
6	Present in 50%–59% of subplots
5	Present in 40%–49% of subplots
4	Present in 30%–39% of subplots
3	Present in 20%–29% of subplots
2	Present in 10%–19% of subplots
1	Present in up to 9% of subplots
r	Recorded in census but unrecorded in empirical survey

An Index of Distribution (IoD) may also be derived from the frequency data for plots. In general, the more widely distributed a species is, the more plots (as opposed to subplots) it would have been detected from. As such, the distribution of a species may be represented according to the suggested scheme below:

Index of Distribution	Criterion
5	Present in 80%–100% of plots
4	Present in 60%–79% of plots
3	Present in 40%–59% of plots
2	Present in 20%–39% of plots
1	Present in up to 19% of subplots
r	Recorded in census but unrecorded in empirical survey

Each species would therefore be represented by indices related to its occurrence and distribution. Although not strictly quantitative (being based on presence/absence data), these indices would permit comparison of independently reproducible data from one monitoring session to the next.

The frequency data, summarised by the IoA for each species under consideration may be subjected to various treatments in order to elucidate any trends in community structure from one monitoring session to the next. Species with an IoA represented by r would be omitted from subsequent analyses.

Graphical representation of IoA across monitoring sessions

A table containing the IoA for each species in two successive monitoring sessions (henceforth referred to as S1 and S2) would be prepared for each plot in the area of study. The data would subsequently be represented as a scatter diagram on two orthogonal axes, each axis representing the IoA for a specific monitoring session. For the purposes of standardisation, the data for S1 is plotted on the x-axis and that for S2 on the y-axis. Each species is represented by a single point defined by its IoA in S1 (x value) and S2 (y value). The behaviour of the line of best fit through the points may be assessed by assuming four extreme scenarios:

(1) If the community state in the two successive monitoring sessions is identical, the line of best fit would be characterised by a slope of +1 and a y-axis intercept of 0 (**Figure 1**).
(2) If the community state in S1 and S2 is precisely complementary (i.e. species with high IoA in S1would have low IoA in S2 and vice-versa), the line of best fit would have a slope of –1 (**Figure 2, Figure 3**).
(3) If no species are recorded in S1 and some are recorded during S2, the line of best fit would be coincident with the y-axis.
(4) If some species are recorded during S1 and none during S2, the line of best fit would be coincident with the x-axis.

In general, the slope of the line of best fit represents the overall correlation in variation of IoA across different species whilst the position of the intercept on the y-axis reflects fluctuations in overall IoA across all species (**Figure 4**).

This procedure may be carried out for each plot, indicating the rate of community change in each part of the area of study. Such graphical representation may also be carried out across the whole area of study, using the combined data from all plots, indicating the rate of community change across the entire area of study.

Cumulative change

The cumulative data obtained for each session may be used to chart the species-state of the community from one monitoring session to the next. This may be carried out using various multivariate ordination techniques, including Polar Ordination and Principal Components Analysis, amongst others (Kent & Coker, 1999; Waite, 2000).

The starting point of this procedure would be a matrix listing the IoA of each species in each plot. This matrix is successively reduced into a components matrix, where components represent highly correlated combinations of the original species. The results derived from ordination would be plotted on a scatter diagram where each point would represent a plot within the area of study. The position of each point is defined by its values on the components being utilised as axes. The ordination diagram obtained by plotting all the available points would permit the relationships between different plots (in terms of species composition and IoA) to be appraised by visual inspection. The effort-intensiveness of ordination procedures is offset by the

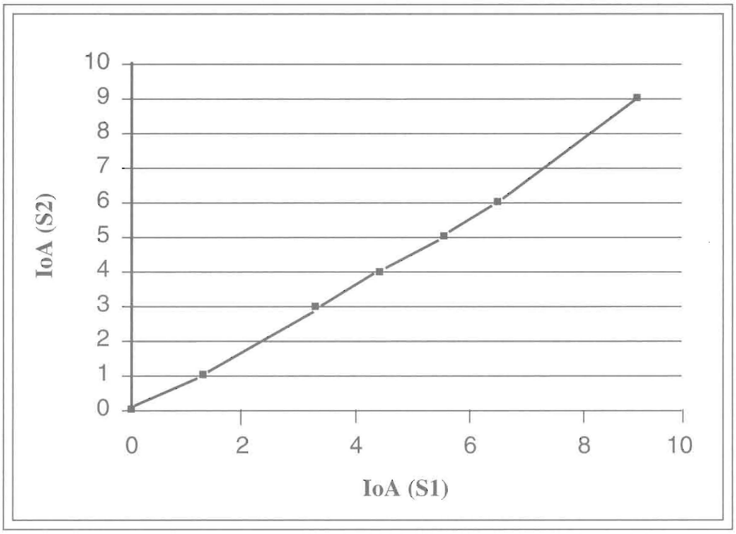

Figure 1. *IoA plot with community structure unchanged.*

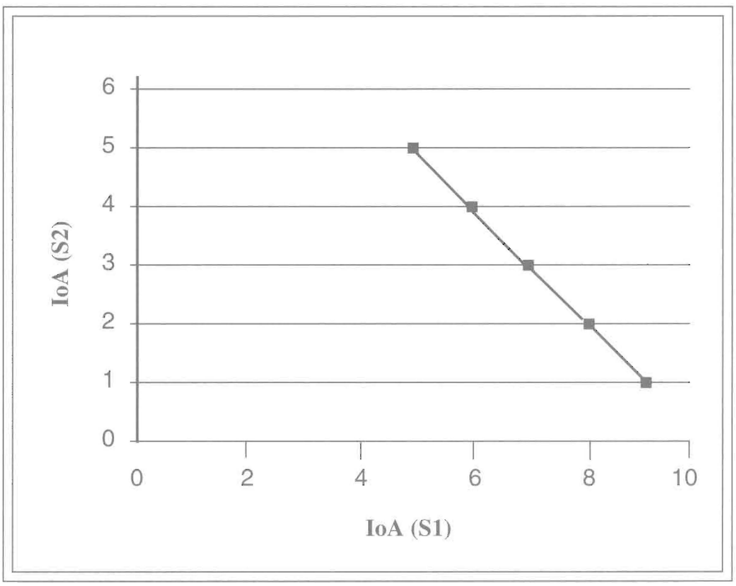

Figure 2. *IoA plot with complementary community states.*

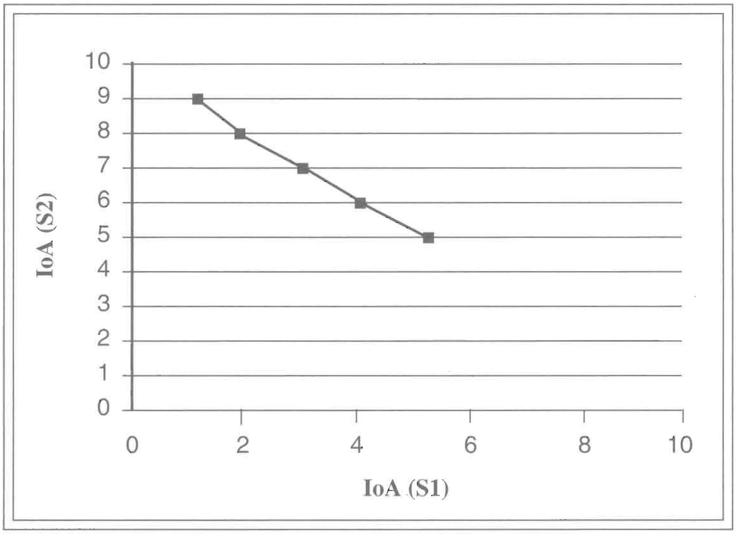

Figure 3. *IoA plot with complementary community states.*

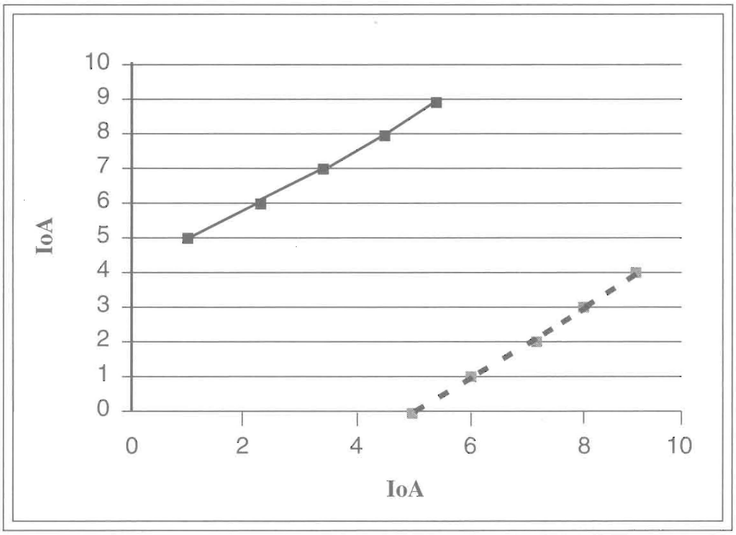

Figure 4. *Behaviour of lines of best fit in response to an overall decrease in species abundance. The solid line represents the change in community state between S1 and S2; the dashed line represents change in community state between S2 and a third monitoring session, S3. Plotting the data from three sessions on the same scale and axes suggests that a reduction in overall abundance is reflected in a decrease in the value of the intercept on the y-axis. This hypothetical scenario assumes that relative abundances between species remain relatively unchanged across monitoring sessions, i.e. that all species abundances have been reduced by an identical amount.*

benefits of summarising variation within data and correlating such summarised data sets with environmental controls.

Conclusion

Monitoring of plant communities requires estimation of the variation in relative or absolute abundances of selected species over time with the general objective of establishing whether the plant community being observed is changing and whether such change is correlated with an observable environmental factor or suite of factors.

The implementation of monitoring programmes is generally restricted by constraints of time, cost and availability of human resources. As such, qualitative assessment is frequently the simpler and quicker option. Nonetheless, the results of such qualitative surveys often reflect the competence and experience of the observer as well as inherent changes in community state. In general, observers tend to overestimate the coverage of species which are in flower, conspicuous or familiar and underestimate others (Kent & Coker, 1999).

The introduction of a quantitative element increases independent replicability of results by reducing dependence on the properties of the observer. As such, the results obtained would have a greater tendency to reflect actual changes in community state. The quantitative aspect would certainly increase effort-demand. However, such a change is expected to be within the limits of cost-effectiveness since it only involves the determination of presence or absence of species within each subplot.

The stratification of the area of study into plots enables comparison of the same general portions of habitat over time. In this way, the investigator may not merely detect community change, but would also be aware of the areas in which such change is most pronounced. The derivation of an Index of Distribution would also enable the proliferation or range-reduction of individual species to be detected at an early stage.

Assessment of any change that may have occurred between one monitoring session and the next is dependent upon the evaluation of individual investigators. Although this subjective element remains (and cannot be dispensed with), such individual evaluation would be based on a quantitative foundation rather than on an exclusively visual assessment. If baseline studies are available, this would be carried out by observing whether the amplitude of differences following disturbance are comparable or greater than shifts caused by natural change.

This method has been tested with computer-generated scenarios and has enabled detection of species shifts in modelled communities. The applicability of this procedure in the field has not yet been tested thoroughly and such testing is scheduled for 2004 and 2005.

References

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WAITE, S. (2000). *Statistical Ecology in practice*. Prentice-Hall, 2000.