A PERSPECTIVE ON INDICATORS FOR SPECIES DIVERSITY IN DENMARK

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-- Parallel Session --

Group 2-A. Wild Species Dependent or Impacted by Agricultural Activities

Monday 5 November 2001

Paper presented to the:

OECD Expert Meeting on Agri-Biodiversity Indicators
5-8 November 2001
Zürich, Switzerland

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A Perspective on Indicators for Species Diversity in Denmark

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Abstract
The concept of species diversity and the concept of indicators are reviewed in the context of the Danish agricultural landscape. It is argued that diversity per se can be misleading if no account is taken of geographical scale, rarity and uniqueness. Indicators should reflect identified core-problems, and the nature of these problems depends on what part of the agricultural landscape we are dealing with. A classification of habitats according to their naturalness is proposed, and it is shown that the political interest in species diversity will depend on the degree of naturalness of these habitats. It is also shown that different species groups have different specificity and habitat requirements. Despite this variation, it is argued that political interest with regards to species diversity inevitably concentrates in semi-natural and uncultivated habitats. For these habitats, examples will be given of the most urgent political/biological problems/threats, and existing indicators for assessment of status and trends with respect to these problems will be discussed. It will be shown that the available statistical information in the case of Denmark does not meet the requirements for a national indicator of species diversity. A slight modification of the current OECD indicator for species diversity is suggested, and the reasons for and implications of this modification is described and discussed.

Introduction
An essential starting point for selection of indicators is a specification of selection criteria that is to be met for an indicator to gain common acceptance and wide use. OECD (1999) has specified the following useful criteria for agri-environmental indicators:

- **Policy-relevant**. The development of indicators should be driven by demand (issue) rather than supply (data). Indicators should address the key environmental issues faced by governments and other stakeholders in the agricultural sector.
- **Analytically sound**. Indicators should be based on sound science. It is acknowledged though, that the development of indicators may involve successive steps of development.
- **Measurable**. Indicators should be achievable in terms of current or planned data availability and cost-effective in terms of data collection, processing and dissemination.
- **Easy to interpret**. Indicators should make it easy to communicate essential information to policy makers.

It is suggested that species diversity can be regarded as one such policy-relevant environmental issue – but further definitions and clarifications are needed before we can proceed with the development of diversity-indicators.

First it should be acknowledged that the documentation that human exploitation of space and natural resources has caused and still causes local and global extinction of species and populations is the major reason for diversity being a prioritised political issue. The magnitude of mammal extinctions during the period of global expansion of humans has been compared to natural catastrophes in the history of the earth caused by meteors (Eldredge 1999). Today, we not only interfere directly with other species, but also change the basic ecological conditions for life. In the context of agriculture, it is worthwhile to remember that he so-called “global change” not only includes changes in atmosphere and climate, but also changing land use.

Species diversity may be defined as the number of species living in or using a certain area. If we consider an area smaller than the global area, different processes working on different spatio-temporal scales (Zobel 1997) may cause the observed variation in species diversity. First, speciation is responsible for the size and composition of the global species pool, i.e. the diversity that may theoretically populate an area. Speciation is a very slow process that works on an evolutionary time-scale spanning millions of years. Second the migration of species is responsible for the size of the local species pool that may eventually populate an area. This process is slow too, but nevertheless implies no more than 12.000 years in Denmark being glaciated during the last glacial period. Migration may be said to occur on a historical time scale. Finally, the environment and the biological processes (competition, disturbance, predation etc.) work as a filter on the species pool determining how many species will eventually be able to live in a certain area. The processes shaping the environment may be said to work on an ecological time-scale, where present and near past are of overall importance.

It is obvious that processes on evolutionary time-scale are hardly impacted by the “young” human species, whereas the migration of species, and especially the shaping of the ecological conditions have a strong human footprint.

It follows from this that variation in species diversity can have several reasons, but it is only a political issue if a declining diversity is caused by human interaction with the environment or directly with the species. An indicator of species diversity should be able to distinguish between naturally species poor areas (e.g. a raised bog) and artificially impoverished areas (e.g. rotational improved grass fields with Lolium perenne and Trifolium repens). Although the drainage of a bog or the liming of a species-poor acidic grassland may lead to increased diversity, neither of these activities would be desirable from a conservation point of view. A sensible interpretation of trends in diversity therefore relies on a simultaneous monitoring of agricultural pressures on the habitats of the species.

If we accept that trends should be interpreted in the light of agricultural pressures, we will have to think about what we consider as an agricultural pressure. There is a general agreement that artificial fertilisation and draining are negative agricultural pressures, whereas extensive grazing of semi-natural grasslands is to be considered a desirable agricultural activity. The reason for this, I would argue, is that grazing works as a natural disturbance to which a lot of species are adapted, and grasslands may be considered one possible natural successional state in a given environment. Fertilisation and draining on the other hand changes the environment away from its natural state.

Where as this concept of “naturalness” may be applied fairly easily to permanently uncultivated habitats, it does not apply very well to the cultivated fields. Here the main objective is to keep the environment in an artificial highly productive and frequently disturbed state. Species diversity may still be an issue, but as we will see below, probably not the major issue and the definition of human pressure has to be pragmatic, acknowledging that naturalness is not the objective.

Patterns of species diversity

It should be acknowledged that diversity would always depend on area. Table 1 shows data on diversity of vascular plants collected in plots of 49 m^2 from habitats classified as either “agricultural” or “semi-natural/natural”.

Table 1. Diversity measures for open habitats of the agricultural landscape.

Measure	Test	Semi-natural/natural (n = 410)	Agricultural[2] (n = 206)	Probability
Species richness (native species)	Wilcoxon test	16.4	16.9	P>0.05
Percentage samples with semi-rare species	Chi-square test	38	27	P<0.01
β-diversity in 10 random draws of 40 plots[1]	T-test	12.96	9.42	P<0.001

1. β-diversity is calculated, as the total number of species divided by average number of species per plot.
2. Agricultural differs from semi-natural by being either young successional stages of abandoned fields or improved grassland.
Source: Ejrnæs et al., forthcoming.

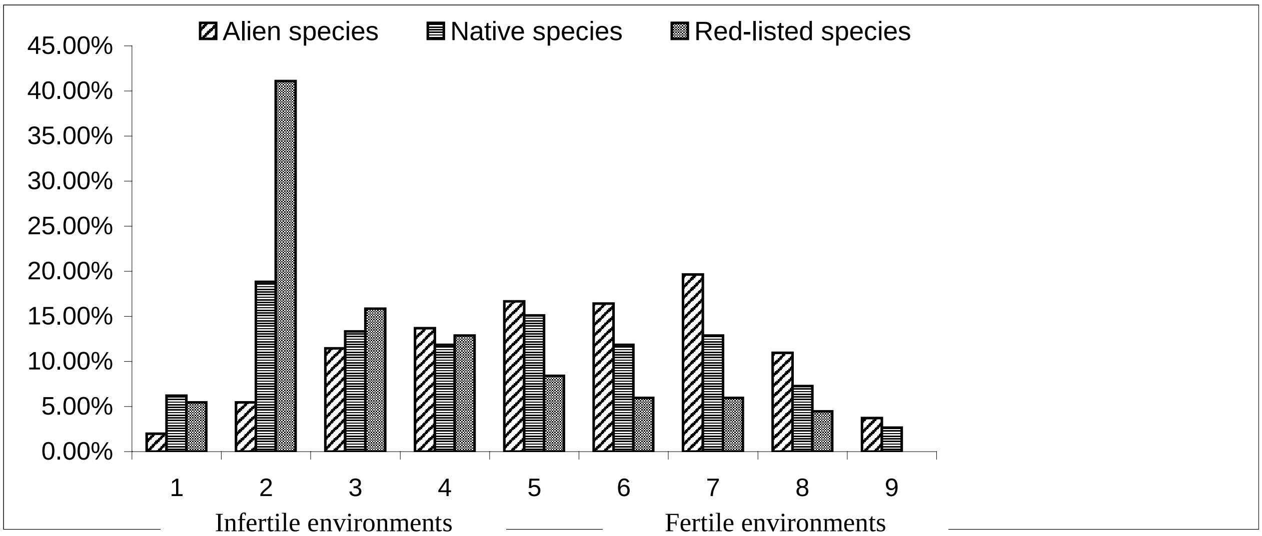
No difference was found with respect to mean number of native species per plot. But significant differences were found with respect to the occurrence of uncommon species and β-diversity (i.e. total number of species divided by average number of species per plot). The conclusion is that although the small-scale diversity was the same, species inhabiting habitats classified as agricultural were generally common species that occurred in many plots.

As we proceed from local scale to larger scales, the contribution of rare species to the total species number becomes increasingly important – a common species may be decimated by 50 %, and still be present in every 5 x 5 km square of Denmark. This is not the case for rare species.

If we look at the red-listed species, these have particular affiliation to natural and semi-natural habitats. Stolze & Pihl (1998) give a habitat-summary, and of 3142 red-listed species, only 15 species have rotational fields as habitats and 19 species have marginal biotopes such as hedgerows as habitats. On the other hand 485 species live in dry grasslands, 148 species live in heathlands, and 328 species live in bogs, fens and mires. 1699 red-listed species have forests as habitat.

One of the proposed reasons for declining biodiversity in the agricultural landscape is eutrophication (Ejrnæs 2000), and a quick look at the species preferences to environmental nutrient levels (Figure 1), confirms that a large proportion of the native Danish flora requires nutrient poor habitats. If we look solely on red-listed plants this preference is even more pronounced. Opposite to this picture, the alien species of the Danish flora clearly thrives under fertile conditions (Figure 1).

Figure 1. *Preferences of the vascular plant flora in Denmark with respect to nutrient level of the environment (Ellenberg et al. 1992). Bar height indicates the percentage of alien, native and red-listed species prefering a certain nutrient level. Nutrient levels follow Ellenberg, and can be interpreted so that values from 1-4 (5) cover most of the variation in unfertilised wetlands, grasslands and heathlands, whereas values from 6-9 cover fertilised areas and naturally productive habitats such as swamps. Source: Ejrnæs (2000).*



The reason for the overwhelming importance of natural and semi-natural habitats for large-scale species diversity is that the majority of species have specific evolutionary adaptations to specific environmental conditions – they show habitat-specificity. Although this is certainly true for most rare Danish species, including plants, mosses, lichens, fungi and invertebrates, there are some noteworthy exceptions, especially among the larger animals. Mammals and birds often show some habitat specificity, but also often have the capability of adapting to a changing environment. For a considerable number of mammals and birds, the habitat requirements can be summarised to “pleasant, unspecified food”, shelter and low hunting pressure. These species will often depend on the architecture of cultural landscapes and the disturbance regime more than on the conservation of natural and semi-natural habitats.

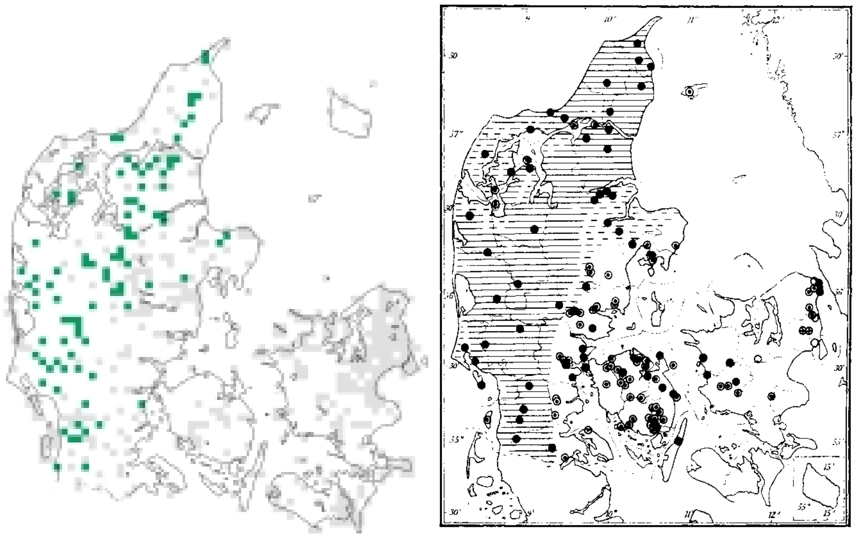
Species numbers as indicators of species diversity

The obvious solution to the problem of monitoring the status of species diversity would simply be to carry out repeated counting of the number of species. Now, given that we are dealing with an unknown number (far above 10.000) of species, even in a small species-poor country as Denmark, this is clearly not feasible.

A number of other species-based approaches should be mentioned. Denmark, like other countries, has a tradition of producing updated Red Lists for a large number of species groups. These Red Lists are national and may indicate the trends in abundance and distribution of very rare species. The Red List have several problems however. First there is an ongoing standardisation of Red List categories, and before this work is finished, one Red List cannot be compared quantitatively to another. Second, Danish Red Lists are not based on standardised inventories, but on the present knowledge of specialists. Knowledge of the frequencies and distribution of rare species is therefore highly dependent on the time-resources spent by specialists, and this will inevitably vary over time. If we restrict data collection to include only those species groups that are very well-known, e.g. orchids and birds, we risk to get a picture that is highly biased due to the high conservation effort put into these prioritised groups of species.

Another opportunity for species data is atlas projects, mainly carried out by non-governmental organisations. Unlike Red List data atlas data are standardised and geo-referenced, which is optimal for comparison over time. Unfortunately atlas-inventories typically span several years and the amount of labour and resources put into such inventories make them less suitable for frequent replication (Figure 2).

Figure 2. *The present (to the left) and former (1961) distribution of a declining plant species in Denmark, Arnica montana. In green squares, the species has been found, and in grey squares the species has not been found, the remainder of the country has not yet been examined. Although this map is the result of almost 10 years of inventory of vascular plants in Denmark, full coverage is not yet within reach, and replication cannot be expected within the next 50 years.*



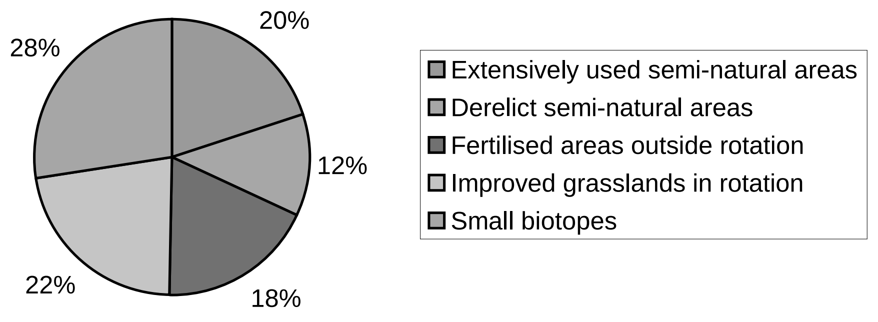
Apart from these problems it should be acknowledged also that Red Lists and Atlas projects are not specific to the agricultural landscape, and therefore observed trends may be hard to relate to agricultural developments (OECD 2001).

An alternative to full coverage data is data collected repeatedly in standardised ways in the same permanent plots or transects, selected to be representative of the agricultural landscape. Such data are promising, but up till now only exists for birds in Denmark (e.g. Ellemann et al. 2001).

Habitats as indicators of species diversity

We know from the Red List that certain habitats are important for diversity, and we may therefore choose to monitor the area and condition of selected habitats rather than monitoring the species directly. A precondition for this is reliable data for identifying and quantifying the area and distribution of target habitats, and reliable data for monitoring the conditions of target habitats over time. Although we do have methods for identifying such target habitats from their land-use history or their species composition, we do not have data. Given the lack of data, authorities tend to operate with categories of habitats that are at best very uncertain or sometimes even useless. An almost useless category is “permanent grassland” which includes semi-natural habitats, but also intensively grazed fertilised grass fields dominated by forage grasses (Figure 3). Another category is protected habitats according to the Danish legislation on nature protection, but the actual mapping of this habitat category included cultivated meadows, and was also carried out under time pressure. Therefore the mapping often relied on subjective inspection of areal photographs, and has turned out to include habitats under heavy agricultural influence (fertilised or recently cultivated)

Figure 3. *A quantification of different categories of uncultivated areas in the Danish agricultural landscape. The quantification is based on a small stratified inventories and should be considered highly uncertain. Extensively used semi-natural areas is the target habitat class for conservation of species diversity. Source: Ejrnæs & Andersen 2000.*



Suggestions for further indicator improvements

OECD (2000) suggest the following indicator under IV.5:

- *Trends in population distributions and numbers of wild species related to agriculture.*

Obviously the issue of diversity is complicated, and it is not a surprise that the definition of this indicator is fairly broad and that common OECD standards for methodological measurements have yet to be established. It is also clear that the collection of data needed for a reliable indicator of this kind is a tremendous task.

Based on the discussion of species diversity presented in this paper, I suggest a slightly modified indicator:

- *Trends, that can be related to agricultural pressures, in population distributions and numbers of wild species.*

The objective of this change is to make it clear that changing diversity can have many causes, and that a declining diversity is only a political issue if it is caused by a human pressure on the environment. It should be acknowledged that this definition raises a need for a further definition of agricultural pressures:

- *In semi-natural and natural habitats, agricultural pressures are defined as activities that move the environment away from its natural state*
- *In cultivated habitats, agricultural pressures are defined as any activity that has a negative influence on the amount of non-crop life, above and below ground.*

The first step in development of operational indicators following these definitions would be to make a priori lists of pressures for different kind of agricultural habitats or habitats under influence from agricultural pressures, and start looking for indicator species for the diversity affected by these pressures (e.g. Table 2). The second step would be to identify relevant species groups indicative of changes caused by identified pressures (Table 2). The final selection of species groups should represent a trade off between sensitivity as indicator and amount of resources required for repeated monitoring.

Table 2. Sensitivity of different species groups to recognised agricultural pressures in semi-natural meadows and grasslands.

Pressures	Vascular plants[1]	Bryophytes[2]	Birds[1]	Butterflies[2]
Fertiliser application	+++	+++		+++
Dereliction	+	+++	+	++
Drainage	+++	+++	+++	+++
Fragmentation (e.g. past habitat destruction)	+		+	+++

1. Easy to identify and count.
2. Complications regarding sampling or species identification.

The monitoring will eventually be carried out as some kind of repeated stratified sampling across the agricultural landscape (Ejrnæs 2001). Data collection should include statistical data on agricultural pressures with due reference to specific habitats (extensive part) and field data on the distribution and diversity of species (intensive part). The extensive part should imply the collection of land-use statistics from a large number of farms. Some of these should be chosen from a subjectively selected subset to ensure the inclusion of an appropriate sample of prioritised habitats (semi-natural and natural habitats). The extensive part should be based on land-use statistics collected at farm level, with recording of the development in the most important agricultural pressures. These include e.g. deposition of ammonia, derelection of semi-natural grasslands and meadows, fertilisation, rotation, clear-cutting of scrubs and small woodlands and drainage (Ellemann et al. 2001). The precondition for the extensive part is an initial mapping and classification of monitored habitats that reflects the quality of habitats for rare habitat-specific species. This initial mapping might be produced in collaboration with a current initiative to implement a new “nature plan concept” for collaborative on-farm planning for conservation and promotion of wildlife (Tybirk & Haugaard 2001).

The intensive part should imply a subset of the extensively surveyed farms, and consist of effect-measurements on a selected section of the biota. The selection of species should include different species groups measured in appropriate units and scales. The selection of habitats should include all habitat categories but avoid over-sampling of overly represented but ecologically redundant habitat types (e.g. rotational fields). If resources are scarce, rotational fields should be left out acknowledging that despite their vast area they should be considered less important contributors to biological diversity.

The OECD report (2001) refers to an intensive debate about abundance versus richness measures. To this I would reply that given a large number of samples of a large number of species from sufficiently small plots, presence-absence data could provide reliable and sensitive indication of diversity trends in the agricultural landscape. If planned and carried out carefully, such a stratified sampling of selected habitats and species of the agricultural landscape could fulfil the criteria defined by OECD (1999).

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