

## **Time lags in biodiversity response to farming practices**

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### **Summary**

Agri-environmental schemes have been applied with the goal to mitigate negative effects of agriculture on biodiversity and ecosystem functioning. However, on evaluating the schemes the results have been variable and shown both positive and neutral effects. These variable effects can be attributed to not taking into account important factors affecting the variables at test, such as biodiversity. These factors include *no exact definition of the farming practice, landscape complexity and the scale of study*. Here we introduce a fourth factor not considered, the *time scale* of study. The implications and effects are discussed shortly.

### **Introduction**

Since the appliance of landscape ecology in the research fields, of e.g. conservation, we have got an increased understanding of how organisms and biodiversity are affected by environmental disturbances. For instance it has been shown that the effect of organic farming depends on the landscape context the organisms operate in (Rundlöf *et al.*, 2008; Heard *et al.*, 2007). Still there are varying results from the studies of effects of farming systems.

#### *Why variable results?*

Rundlöf & Smith (2006) listed some examples of why many studies comparing organic and conventional farming have varying results, which we summarize in three groups. (1) *No exact definition of the different farming practices*. There is a degree of heterogeneity in how organic farms are managed despite the common rules given by European Union and the Swedish KRAV certifications because each farms is managed by an individual farmer. (2) *Landscape complexity and heterogeneity differences*. There can be biases in where organic farms are located relative to conventional farms; often organic farms are located in already diverse and heterogeneous areas (Rundlöf & Smith, 2006; Gabriel *et al.*, 2009). Landscape complexity is sometimes not included in the analysis and this can affect the outcome. (3) *The scale at which the study is performed*. Studies performed on small scales as single plots or fields without considering the surrounding landscape can show greater differences than studies performed on larger scale Bengtsson *et al.* (2005). We may add a fourth bias (4) which can result from *not considering historical processes*, e.g. how long the farm has been managed under the agri-environment schemes. If diversity and ecosystem services change through time this must be considered in the study design when comparing two farming practices.

Different types of land-use effect curves of the organic farming practice have been proposed.

- (1) The highest benefit to biodiversity should be in extensively farmed areas as these already have a high biodiversity which then is protected from intensification or abandonment Kleijn & Sutherland (2003).
- (2) Bengtsson *et al.* (2005) concluded from their meta-analysis that organic farming is most effective in intensively managed agricultural landscapes.

(3) A humped shaped relationship was proposed by Tschardtke *et al.* (2005), where the intermediate heterogeneous landscapes benefited most from agri-environmental schemes.

All of them evaluate the positive effect of organic farming as an increase of biodiversity, what Kleijn & Sutherland (2003) call ‘*improvement effects*’. A second effect is the ‘*protection effect*’ which is thought to be greater in extensively farmed areas Kleijn & Sutherland (2003). This could show up as having a greater effect with time. This time effect is another factor which has been rarely taken into account in studies of environmental disturbances, e.g. farming practice.

We can ask what happens if we add this additional and missing axes in the diversity-landscape graphs when evaluating where the effects are greatest. Will the benefit curve change with time? If biodiversity increase with time, it could change the benefit curve if the organic farms not only effects the immigration and survival of species but also acts as a rescue from extinctions from the regional pool, the ‘*protection effect*’. This could increase the benefits of organic farming in heterogeneous landscapes with time.

The historical legacies of past land use and landscape change should be taken into account more in future studies to evaluate this.

### How Do We Study Historical Processes?

Historical influence on diversity can be studied by e.g. “ghost hunting” (Nagelkerke *et al.*, 2002) by comparing the match of species distribution and richness to historical and present landscape configuration, (e.g. Lindborg & Eriksson, 2004). Another alternative is to analyse the statistical relationship of species present, or absent, and the past land use Harding *et al.* (1998). However, there are some possible problems when studying historical processes, e.g. landscape change, farming practice change and biodiversity changes. Swetnam *et al.* (1999) were mainly concerned about the brief and often fragmented record of the past, and for many processes there is a lack of past history records. Another problem is that the reliability, extent and completeness of historical records fade as we go back in time. It may also be difficult to separating factors in the landscape from historical processes as they can be auto-correlated. Another possibility to study how historical events affect the ecosystem functions or diversity is to compare present landscapes that have undergone a known historical event, with different time since that event occurred. This can then be used to make correlations between present day landscapes similar in context but differing in time since the event of interest occurred. These studies all have the common problem that all other space-for-time studies suffer from. That is the assumption that all the landscapes under study are changing, or have gone through a change, at a similar rate.

### Taking Temporal Scale into Account

The temporal axis is quite often neglected in ecological studies, maybe because it is hard to take into account and study, but it is nevertheless important. Studies on how historical processes can affect biodiversity shows that landscape context of the past can be as important as present day landscape context (Lindborg & Eriksson, 2004; Bisonette & Storch, 2007).

Over time small structures in the landscape will naturally change. The larger structures, whole landscapes, will eventually change either by means of small directional changes in small scale structures or with large sudden catastrophes.

Population demography does not always change at the same rate as the landscape and its resources change, Fig. 1, With (2007). Thus there can be a time lag in the disappearance of species after a patch has become a sink, something ecologist’s has named *extinction debt*. Time lags can also be present after a recovery, i.e. an increase in quality. Even if a patch increases its quality, it will take some time before organisms colonise the patch. How long will depend on the organism’s ability to disperse and the landscape context and connectivity, which is known as the *colonization credit*,

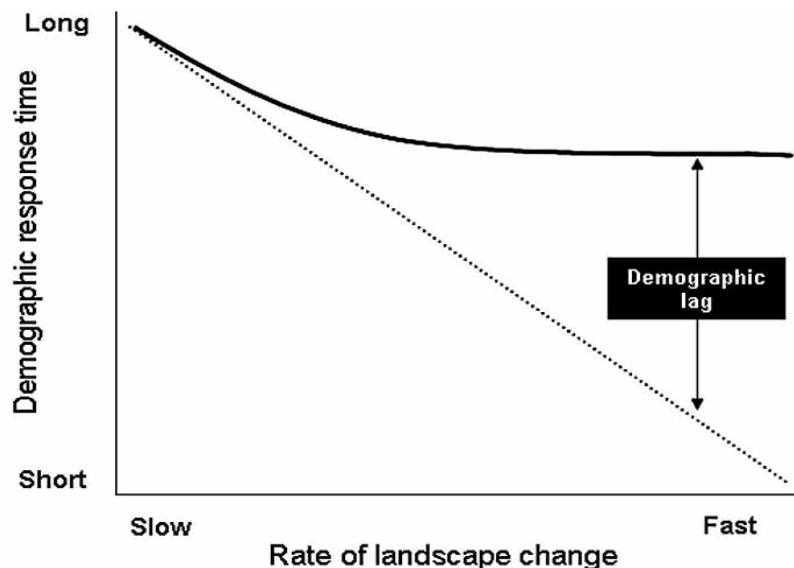


Fig. 1. High survival or longevity of individuals can result in a lagged response to landscape change, from With (2007).

With (2007). There are some evidence of this being the case, Taylor & Morecoft (2009). Other factors than slow colonisation, such as organisms with low fecundity or survival in poor habitats can affect the lag time in recovery, and the organism thus respond slow to increased habitat quality. After a change in habitat use, such as a restoration or new farming practices, that will improve a habitats quality, the actual increase in quality can take time which correspondingly can cause a time lag in biodiversity response.

Lindborg & Eriksson (2004) showed that vegetation in grasslands more reflected historical habitat extensions than present day grasslands. Thus present day diversity can be a mirror of historical processes and former habitat size and shape. The conversion to organic farming has a possibility to change the patch structure and habitat quality on the farm. Patch structure and quality will, if so, probably change over time and not instantly, how fast depend on how much the management differ from conventional farming and the characteristics of the changing structure itself, i.e. if it is a structure with high inertia or a fast responding structure. These small step processes, occurring as a result of a change in farming practice, can make the benefits of organic farming greater over time. Such benefits will not be discovered in a comparison to conventional farming without taking historical processes into account.

These are processes acting over relative large temporal scales but there can also be variations on a finer temporal grain, e.g. diversity and abundance can decrease over time, but both decrease and increase between years. A short term inventory, over for instance a season or comparing 2 years, may then reflect a temporary decrease in abundance even if the long term effects actually is an increase. Time lags and historical legacies need not always have a strong influence on ecological processes but need to be considered.

## Discussion

Landscape ecology has strengthened the understanding of the effects of agri-environmental schemes on biodiversity and how it should be monitored. However natural processes change through time and do that at different rates in respect to each other and to the surrounding landscape. This can obscure monitoring programs which compare farming systems and measurements taken in the landscape to benefit the environment, e.g. biodiversity. To further enhance the understanding of how farming practices affect biodiversity, the time lags of population responses and ecosystem functions should be taken into account in the monitoring programs. To develop new insights and methods where temporal processes are considered can make it easier to mitigate the existing problems of space-for-time studies. These could be announced for instance when we compare, e.g.

biodiversity, in sites with different proportions of a certain habitat. For example, let us suppose, we study differences in biodiversity between landscapes with high proportions of pasture, with landscapes with low proportion of pasture. If we then, as in a space for time study, use the information to get a picture of what we can expect to happen to biodiversity in the landscapes with high proportions of pasture, if they lose pastures, to resemble the landscapes with low proportion of pasture. Then we can risk to draw the wrong conclusion because of, for instance, the rate of the landscape change is not taken into account. The other example is then when we compare sites with different farming practices without knowing their landscape history.

A factor often totally forgotten in studies of farming practices is the farmer. She or he has, of course, individual interests in, feelings about and relationships to nature and nature conservancy. As a consequence the farmers, even when acting under the same scheme, will adopt different approaches to solving problems and also how much, above the scheme practices, they do that can benefit biodiversity Ahnström (2009). Future work should focus more on interdisciplinary studies where also the social aspects of farming are considered.

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