The arable seedbank as a source of biodiversity and a reliable indicator of field management

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Seedbank-based plant populations have been a feature of arable fields since the beginning of farming. Many of the species that are now regarded as weeds were present at the last glaciation or else brought to the UK from Europe by migrant farmers in the Iron Age and later periods. These arable plants are primary producers, along with the crop and boundary vegetation. They retain structural and chemical diversity in canopies and root systems, and accordingly support many more species of herbivore, decomposer, predator and parasitoid than the crops themselves. Most of the species in these functional groups are not detrimental to crops and many of the predators and parasitoids attack crop pests. The arable plants also contribute to stabilising soil and retaining nutrients in the system at times when a crop cover is absent.

However, the disadvantage of arable plants as weeds has received more attention in the past 50 years than their benefits in stabilising the carbon and nitrogen cycles. The balance of energy flux has probably swung so far towards the crop that some important properties of the arable system are in danger of being severely damaged. To define what is an acceptable balance between crop and weed biomass requires a basic understanding of the population dynamics of the arable flora and fauna. To this end, research in arable weed seedbanks at SCRI has intensified in recent years. Topics of interest include -

- characteristics of the pre-herbicide (pre-1960s) seedbank
- the state of the arable seedbank in the late 20th century
- definition of resilient states in the seedbank community, defined by the number of functional types and their spatial distribution
- indicators for assessing the impact on the system of new crop varieties and management, including genetic modification
- mechanistic links between physiological traits and community properties.

Here, we report on progress in several of these topics and indicate recent initiatives.

Pre- and post-intensification seedbanks A steep rise in the intensification of field management occurred between the 1970s and 1990s. The area of the arable land sown with winter (autumn-sown) crops increased markedly, and though the area of cropped land sprayed with chemical herbicide stayed about the same, the practice and type of chemicals used both changed. More different types of active ingredient were used, more applications were made in both autumn and spring, and many of the new chemical affected more weed species than previously. Consequently, the light and nutrients that were available for the weed flora and the wider food web became severely reduced. Many authorities now consider that the seedbank, the weed flora, the invertebrates and the higher fauna have declined, not equally in all parts of the UK, but certainly over very large tracts of arable land. Despite this, the seedbank has resilience. Many of the commonest species in surveys of the seedbank in Scotland in the 1980s and 1990s were observed throughout the 20th century. Few new species have become established –

perhaps only oilseed rape since the 1970s and some of the exotic willow herbs (e.g. *Epilobium ciliatum*). At the end of the 20th century, the seedbank still contained many species, particularly of the *Chenopodiaceae* and *Polygonacea,* that are nutritious and favoured as food for a wide range of invertebrate herbivores and birds. The opportunity is not yet lost therefore to find ways to balance what are perceived as the positive and negative aspects of the seedbank to the benefit of the arable food web. For this, adequate comparators are needed – objective criteria that define the state of the seedbank community and its change in response to physical factors and field management.

Community indicators as guides to field management Data on the seedbanks since 1915 have now been probed to find such comparators. Few early authors gave information on the spatial sampling scheme they used. However, the rank-abundance curve (which can be derived simply from lists of species and their numbers) proved to be a useful indicator of the way the community as a whole changed in response to management (Fig. 1). The curve was similar in several pre-intensification studies, but fell systematically during periods of suppressive management (Fig. 1). Notably, the curve was also induced to rise again to near pre-intensification values by relaxing the management of the 1990s cereal rotations. The seedbank has therefore some resilience.

Knowledge of the numbers of each species and where they are found in a field allows a more useful descriptor to be calculated - the species-accumulation curve. This curve is derived from maps of spatial distributions by working out the average number of species in samples of two, three, four, etc., from the total sample pool. If the same field is sampled over time, say, before and after a change in field management the curve parameters give indications of the way the spatial distribution of floral diversity has been affected.

This method was used to answer the question as to

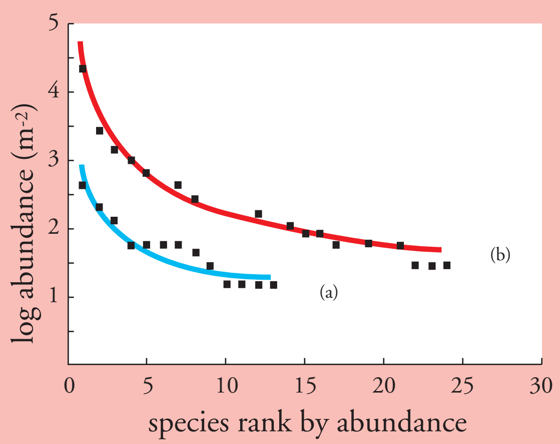

Figure 1 Species ranked by abundance in (a) an early seedbank subject to suppressive management for two years, and (b) a 1990s seedbank in a cereal rotation induced to expand over 6 years by having more over-winter fallow and using fewer herbicide sprays. The starting curve in (a) is similar to the ending curve in (b), showing resilience in the community.

whether seedbanks can be regenerated by treatments such as set aside. The result was consistent across five sites differing in their complement of species. Set-aside increased the slope of the relation in a way that indicated uncommon and rare species had increased in abundance or new species had entered the seedbank at low abundance; there had been relatively little change to the total abundance of seed in the field (Fig. 2). The value of the species-accumulation curve was that it enabled quantitative comparisons between sites that had different complements of species.

The search for a balance in the seedbank Such comparative descriptors of the seedbank community are a

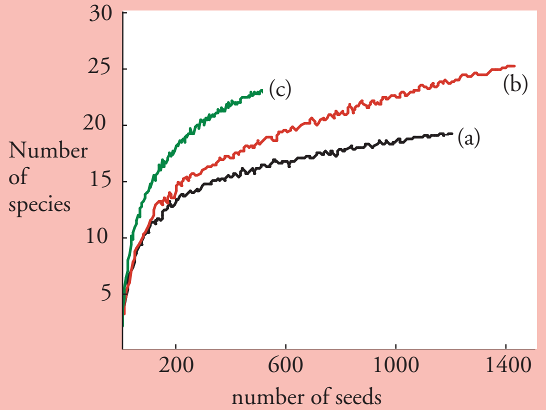

Figure 2 Species-accumulation curves at the end of cereal cropping (a), after five years in set-aside (b) and after return to arable cropping for two years (c).

unique baseline against which to compare developments in arable farming, specially in assessing new crop genotypes, including GM varieties. In this respect, SCRI's knowledge of seedbanks will contribute to the analysis of the Farm Scale Evaluations data, scheduled to be published in 2003. More generally, criteria for the seedbank and the soil habitat will be combined to provide a means for assessing the state and resilience of the arable system. The methodologies will be used to define characteristics of new crop varieties and methods of growing them that should enhance the soil and aerial systems.

What then is the ideal seedbank? Simple models of plant life cycle and seed dispersal are used to search for seedbank communities that contribute much to the food web but little to the weed burden (Fig. 3). The models lead to hypotheses that are being validated experimentally. To date, the communities have been characterised at species level, but the theoretical studies suggest that community-scale descriptors, based on individuals in small populations, should mimic those for species in a field, group of fields or even an agricultural region. If this is shown to be valid, then an individual-based approach to communities offers a possible means to reduce the scale of operations neces-

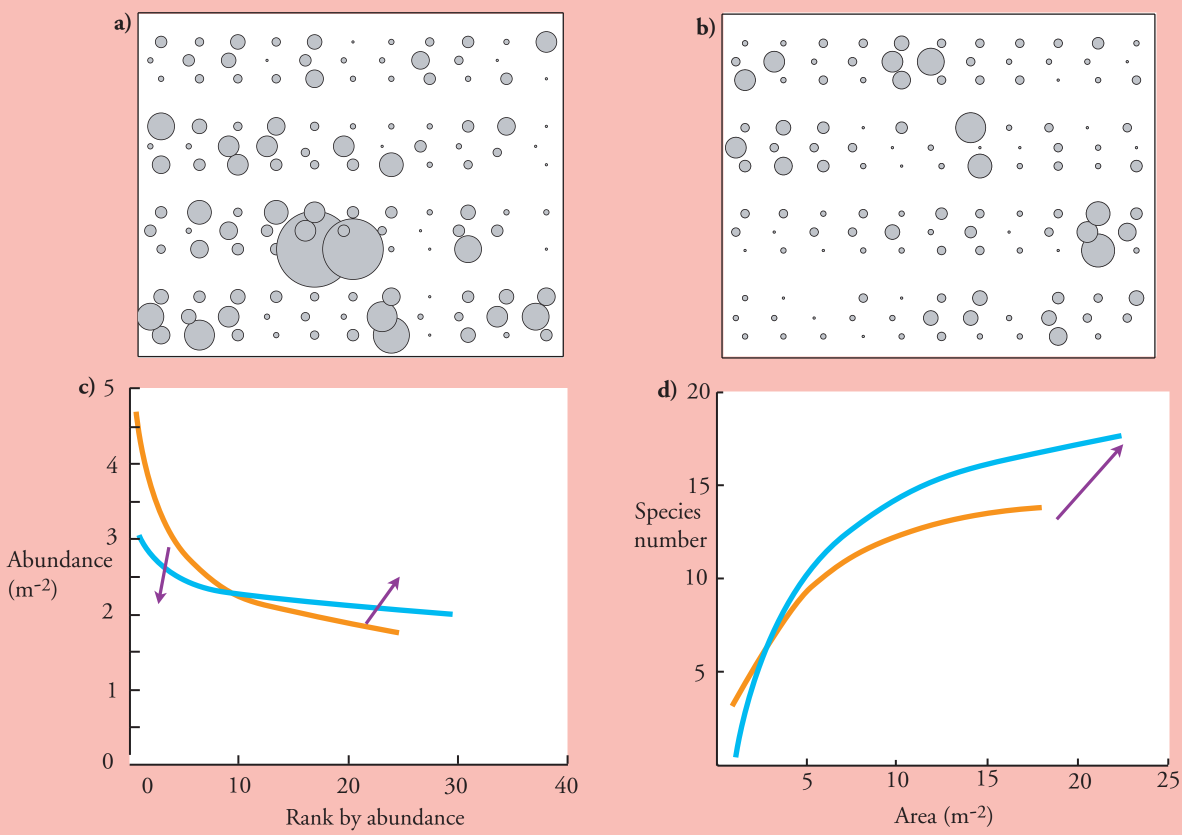

Figure 3 Examples from modelled output of spatial distributions of seedbank density over time (a and b). Models search for species-abundance (c) and species accumulation (d) curves that indicate individuals are more evenly distributed among a wider range of plant taxa or functional types, indicated by the direction of the arrows.

sary in future risk assessments of new biotechnology. New research at SCRI is measuring the genetic and physiological variation in selected species so that experimental populations can be constructed in order to explore the link between plant traits and community properties.

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