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Arable weeds as indicators of agricultural intensity – A case study from Finland

Terho Hyvönen[*], *Erja Huusela-Veistola*

MTT Agrifood Research Finland, Plant Production Research, FI-31600 Jokioinen, Finland

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ABSTRACT

The study aimed at developing an agro-biodiversity indicator based on trophic interactions between 25 common arable weeds and individual groups of farmland birds, pollinators (wild bees), phytophagous insects and insect pests. Each weed species was weighted based on the number of reported linkages with each animal group. Four biodiversity indices based on these weights were constructed and applied to exploring the ecological consequences of long-term changes in weed populations in Finland. Data were used from weed surveys of Finnish spring cereal fields conducted in the 1960s, 1980s and 1990s. The relative importance of weed species varied according to animal groups. Annual weed species able to produce numerous seeds were important for the farmland birds and some perennial weed species were important for the pollinators. The highest number of linkages was established between weed species and phytophagous insects. The number of harmful pest species associated with broad-leaved weeds was low for all species. The general pattern of changes in values of indices over recent decades was similar: there was a marked decline in the values between the 1960s and the 1980s, and a slight increase between the 1980s and the 1990s. These changes were regarded as being a consequence of changes in the intensity of agricultural practices. The slowest recovery of the values was for pollinators. The results suggest that the ecological consequences of changes in the intensity of agriculture can be explored with the aid of a biodiversity indicator based on species interactions. Owing to the differences in the importance of weed species for different animal groups, maintaining weed species richness is necessary to ensure ecosystem services are provided for the higher trophic levels in farmland.

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1. Introduction

Concern about the loss of agro-biodiversity has increased the need to assess sustainability of cropping systems. Sustainability should be assessed not only in terms of crop yields but also by promoting provision of adequate ecosystem services within cropland (Gerowitt et al., 2003). Monitoring populations of organisms associated with farmland provides essential information (Albrecht, 2003; Büchs, 2003). Since monitoring of the whole biota is not feasible, species or species assemblages can represent biodiversity indicators. Exploration of trophic interactions has been increasingly used in studies on potential effects of changes in crop management and land-use scenarios (e.g. Hawes et al., 2003). The same approach might also be applied to monitoring ecosystem integrity, i.e. persistence of plant communities in face of natural or anthropogenic pressures, and their continued support of upper trophic levels. Inclusion of trophic interactions with wild plants in a biodiversity indicator would enable monitoring of ecosystem services provided by primary

[*] *Corresponding author:* Tel.: +358 3 4188 2435; fax: +358 3 4188 2584.
E-mail address: terho.hyvonen@mtt.fi (T. Hyvönen).
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producers. The importance of arable weeds in supporting biodiversity at higher trophic levels in crop fields was recently demonstrated (Marshall et al., 2003).

Arable weeds are primary producers and are of central importance to the arable system food web. Weeds serve as immediate food sources for herbivores and support prey species for higher trophic levels. Weeds can also alter habitats and microclimatic conditions, and provide shelter and suitable reproduction sites for arthropods. The seeds and vegetative organs of arable weeds represent a pivotal food source for granivorous farmland birds (e.g. Potts, 1970; Pulliainen, 1984; Wilson et al., 1999), and flowering plants support communities of wild pollinators (e.g. Bäckman and Tiainen, 2002). Because of multiple interactions within and among trophic levels, weed species support general species diversity at higher trophic levels in agroecosystems (Norris and Kogan, 2005). Decline in the abundance of primary producers has an adverse impact on the species at higher trophic levels (Hawes et al., 2003; Newton, 2004).

Application of intensive cropping measures has been detrimental for the biodiversity of arable habitats. This is especially true for arable weed communities (Erviö and Salonen, 1987; Andreasen et al., 1996; Wilson et al., 1999) since several cropping measures are directed specifically towards reducing weed abundance. A tremendous decline in arable weed populations as a consequence of intensification of cropping measures was reported from Finland (Erviö and Salonen, 1987), Germany (Albrecht, 1995), Denmark (Andreasen et al., 1996), and the UK (Sutcliffe and Kay, 2000; Robinson and Sutherland, 2002). During the same time period, a marked decline in diversity of farmland birds (Donald et al., 2001, 2006), pollinators (Allen-Wardell et al., 1998; Biesmeijer et al., 2006) and other insects (Aebischer, 1991; Benton et al., 2002) has occurred. The contemporary decline in the populations of many groups of organisms associated with farmland (Robinson and Sutherland, 2002; Biesmeijer et al., 2006) raises questions about the importance of the interactions in the decline (Newton, 2004).

Agri-environmental schemes in the EU have been introduced to compensate for the adverse effects of intensive agriculture on biodiversity (Kleijn and Sutherland, 2003; Kleijn et al., 2006). The efficiency of these measures is increasingly evaluated by applying biodiversity indicators (EEA, 2005). Indicators that account for the ecosystem services provided by arable weeds could help in detecting and halting the potential cascade effects through food webs that are a consequence of changing agro-biodiversity. However, although comprehensive literature reviews have been published on the relationships between weeds and various animal groups (Wilson et al., 1999; Marshall et al., 2003; Norris and Kogan, 2005; Holland et al., 2006), no attempts have been made to include these interactions in biodiversity indicators. The development of such indicators requires an analysis of the relative contribution of the species to the ecosystem functions (Kremen and Ostfeld, 2005) and integrating the contributions into an index.

This study aimed to develop an agro-biodiversity indicator based on trophic interactions among common arable weeds and several animal groups associated with farmland. The relative importance of weed species for the animal groups was explored by weighting them by the relative number of weed-animal linkages reported in the literature. The second aim was to demonstrate the application of the indicator to exploration of the long-term changes in ecosystem services provided by arable weeds in Finnish spring cereals. The data from three weed surveys of Finnish spring cereal fields were used for this.

2. Material and methods

2.1. Literature review

An assemblage of 25 weed species (or taxa), representing 15 families (Table 1), was selected for the study. The selected species are common in southern and central Finland (Hämet-Ahti et al., 1998). The 25 species were included in the study because they are among the most abundant weed species in Finnish cereal fields, and the data on their density could be obtained from the weed surveys of Finnish spring cereal fields (Mukula et al., 1969; Erviö and Salonen, 1987; Salonen et al., 2001). The plant species nomenclature follows that of Hämet-Ahti et al. (1998).

The importance of the weed species to granivorous farmland birds, wild bees, phytophagous insects and also to pests of field crops, was studied by conducting a literature review. The numbers of linkages between weed species and animal groups were recorded. If the weed species (in some cases genus) was part of the diet of the particular species, the linkage was recorded as a single observation. Weights for each weed species by animal group were calculated by dividing the number of linkages for each weed species with each of the animal groups by the total number of linkages for the respective animal group (Table 2).

The species list for the Finnish farmland bird community (51 species of which 27 species are seed eaters) was obtained from Tiainen and Pakkala (2000). The information on the weeds as a food source for farmland birds was obtained mainly from the book series of The Birds of The Western Palearctic (Cramp, 1983, 1985, 1988; Cramp and Brooks, 1992; Cramp and Perrins, 1994, 1996) and the review of Marshall et al. (2001). Additional information was obtained from Potts (1970), Newton (1972) and Pulliainen (1984). The information on the flower visits of wild bees (Hymenoptera: Apoidea) to the weed species (74 species visited out of a total of 232 species) was obtained from Elfving (1968).

The information on the linkages between weed species and phytophagous insects (i.e. insects that eat leaves and roots or suck sap; not nectar or pollen feeders) was obtained from the phytophagous insects data bank (PIDB), which is maintained by the Centre for Ecology and Hydrology (CEH) in the UK. PIDB holds some 50,000 records of linkages between British insect species and their food plants compiled from the literature (for restrictions on the use of the database see Ward, 1988). The observations of the PIDB are mostly compiled from the UK but it includes also information from other European countries. The number of linkages for 11 weed species (see Table 2) was obtained from the review of Marshall et al. (2003) and for the remaining 14 species directly from PIDB. When assessing the importance of weeds as hosts of crop pests, in addition to PIDB records, the focus was on

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