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Evaluating consequences of land-use strategies on wildlife populations using multiple-species predictive scenarios

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Abstract

Agricultural activities cause changes to land-use and vegetation characteristics at a smaller temporal scale and at a larger spatial scale than most corresponding natural processes. Simulation models have become important tools to predict future land-use change as a consequence of management policies and in advancing our understanding of the behaviour of complex managed ecosystems. To capture the temporal dynamics and the non-equilibrium properties of agroecosystems and to deal with multidisciplinary trade-offs between economic and conservation interests, it is often necessary for models to be both spatially and temporally explicit and incorporate some component of human decision-making.

This paper presents a multiple-species assessment of land-use change scenarios related to ground water protection and pesticide use in a Danish agroecosystem. A spatially explicit simulation model is used that incorporates the temporal dynamics, driven by weather and farming decisions, of an agricultural landscape in great detail. Numeric and spatial outcome of multiple-species predictive scenarios based on real landscapes and realistic simulations of species behaviour and demographics were captured in simple spatial impact indices. Ecological type species were selected for a range of attributes relevant for specific cases to enable a comprehensive description of a broad species response based on a limited number of species. Five ecological type species, a carabid beetle (*Bembidion lampros*), a linyphiid spider (*Oedothorax fuscus*), a small farmland bird (skylark, *Alauda arvensis*), a small mammal (field vole, *Microtus agrestis*) and an ungulate (roe deer, *Capreolus capreolus*) were used. Simulation results were aggregated into two values indicating the overall numeric response and the overall spatial response of each type species. These two values indicate the change of conditions experienced by a species and thus make it possible to classify large numbers of species according to their general response.

Keywords: Land-use change; Ecosystem; Ecological impact assessment; Individual-based model; Ecological type species; Ripley's *K*; ALMaSS

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1. Introduction

There is probably no other ecosystem on Earth where man-made activities and thereby human decision-making interfere more with natural processes than in intensive agriculture. Temperate agroecosystems, as found for instance in North Western Europe, are under continuous management and are typically the dominating land-use, taking up 50–70% of the surface area. Agricultural activities cause changes to land-use and vegetation characteristics, such as height and biomass, at a smaller temporal scale and at a larger spatial scale than most corresponding natural processes. Consequently, in agroecosystems, biological processes and human decision-making interact to create complex, temporally and spatially dynamic entities.

European and national legislation and management strategies are major driving forces behind land-use and agricultural practices in Europe. A great research effort has therefore been invested in the mechanisms behind land-use change and the behaviour of complex, managed ecosystems (Antle et al., 2001; Rounsevell et al., 2003). Modelling has been one of the most important tools in this process. Comprehensive spatially explicit models are useful to predict future land-use changes as a consequence of management policies (Bell and Irwin, 2002; Musacchio and Grant, 2002; Luitjen, 2003; Schneider et al., 2003; Topp and Mitchell, 2003) and their effects (Irwin and Geoghegan, 2001; Schoorl and Veldkamp, 2001). The dynamic nature of agroecosystems is, however, also a particular challenge to the animal species that are either using the agricultural surface as their primary habitat or depending on natural or semi-natural habitats, whose distribution and quality is affected by agricultural land-use in the surroundings. Attempts to forecast the consequences of land-use change for wildlife distribution and diversity in agroecosystems have typically been based on various GIS-overlay models (Murray et al., 2003) and multivariate statistical models (Jeanneret et al., 2003a,b). Both types of models are spatially explicit, but contain inherent limitations with respect to capturing the temporal dynamics and the non-equilibrium properties of agroecosystems (DeAngelis and Waterhouse, 1987; Antle et al., 2001).

Multi-disciplinary considerations have to be taken into account when trying to forecast consequences of management policies on wildlife, which requires the inclusion of human interests and decision-making in the model. Strong conflicts of interest exist between economic yield (Musacchio and Grant, 2002; Mathevet et al., 2003), environmental concerns (Cryer et al., 2001) and conservation interests (Steiner and Köhler, 2003; Tattari et al., 2003). Even when this is not the case, trade-offs exist between priorities of different wildlife species, since management actions beneficial to some species may have adverse effects on others. This means that even if individual ecological processes and patterns of human decision-making are well-known, large-scale impacts of a given management action may be difficult to predict. Furthermore, the results of such assessments can be difficult to communicate to managers and decision-makers. This has motivated the development of various decision-support tools, most often in the form of GIS-based maps or landscape simulations coupled with stochastic simulation models of population dynamics or individual behaviour (e.g. DeAngelis et al., 1998; Langevelde et al., 2000; Ahearn et al., 2001; Bousquet et al., 2001; Cramer and Portier, 2001; Hof et al., 2002; Mathevet et al., 2003; Rustigian et al., 2003; Topping et al., 2003a).

To assess ecosystem consequences of land-use changes, detailed species-level information often are needed to evaluate the impact of various strategies with reasonable accuracy. At the same time, it is necessary to address species on multiple trophic levels and with various life-history characteristics to pinpoint ecosystem consequences. The result is that very few modelling attempts move beyond single-species case studies. The use of biological indicator species (Lambeck, 1997; Paoletti, 1999; Büchs, 2003) is a well-established phenomenon in ecology. Decision-support models (e.g. DeAngelis et al., 1998; Topping et al., 2003a) also often focus on a selection of species chosen either because they are important for the functioning of the ecosystem (‘keystone species’), because they are particularly sensitive, threatened or generate public awareness (‘focal species’) or because they can be considered representative for a particular group of species or life-history strategies typical for the ecosystem (‘ecological type species’). A further generalisation from ecological type species is to use ‘generic species’ (Hemelrijk, 2002; Parrott and Kok, 2002) designed to capture certain general ecological