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A modelling approach to evaluating the effectiveness of Ecological Focus Areas: The case of the European brown hare

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ABSTRACT

With the current implementation of the Common Agricultural Policy (CAP) for 2014–2020, the European Commission wants to move towards "greener" farming practices in the European Union. Therefore, the EU funds both obligatory measures, such as Ecological Focus Areas (EFAs) through the Green Direct Payment program, and voluntary agri-environment measures. However, empirically evaluating the effectiveness of these measures is challenging. We therefore demonstrate here that mechanistic simulation models are a valuable tool for performing these evaluations. As an example, we use the Animal, Landscape and Man Simulation System (ALMaSS), an established simulation system that has been used to simulate a wide range of farmland species relevant to biodiversity. We analysed the benefits of seven greening scenarios for the European brown hare (*Lepus europaeus*), which has been in widespread decline throughout Europe since the 1960s. We examined the effects of the following EFA types on hare population dynamics: the cultivation of legumes such as (1) peas and (2) beans, (3) permanent and (4) rotational set-asides, (5) permanent extensive grasslands, and (6) herbaceous and (7) woody field margins. The cover of each type was increased separately up to 5% of the area in three Danish landscapes, which are characterised by low hare densities. The effects on female and yearling abundance were observed over a period of 30 years. All greening scenarios had significant positive effects on hare populations. The relative change in female abundance ranged from a factor of 0.4 in the peas scenario to 3.6 in the permanent set-aside scenario. However, only one EFA type, permanent set-asides, led to densities of more than 10 females per km^2 in all three landscapes, which we assumed to be the threshold for population viability. Herbaceous field margins were the second best EFA type, leading to population viability in two landscapes. Our results indicate that overall, 5% coverage with Ecological Focus Area is insufficient to improve the living conditions of the brown hare to a necessary degree. Permanent set-asides seem to be the most valuable type of EFA, but this needs to be confirmed for a wider range of species and landscapes. Using mechanistic simulation models for a suite of representative species, types of agricultural landscapes, and eco-regions could help in achieving the aim of the European Commission to promote biodiversity in the European community via greener farming practices.

1. Introduction

The intensification of agriculture in recent decades is accelerating the loss of habitats and putting many species commonly found in agricultural areas at risk. With the current reform of the Common Agricultural Policy (CAP) for 2014–2020, the European Commission wants to achieve, inter alia, a change towards a more environmentally friendly, sustainable and "greener" agricultural policy in the European Union. Therefore, a new policy instrument, the Green Direct Payment program (European Commission, 2013), was introduced from 2015 onwards, which links direct payments to farmers to requirements for obligatory environment-friendly farming practices, the so-called "greening" of farming (European Commission Regulation (EU) No 1307/2013). "Greening" practices include (1) crop diversification, (2) the maintaining of permanent grassland and (3) Ecological Focus Areas (EFAs). EFAs are areas of ecological interest or measures considered to have environmental benefits. From 2015 on, agricultural holdings with more than 15 ha must establish 5% of their land as an EFA (European Commission Regulation (EU) No 1307/2013). In addition to these obligatory measures,

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the CAP promotes various voluntary agri-environment measures (Council Regulation (EC) No 1698/2005, European Commission, 2005).

However, critical voices have been raised recently, accusing the new CAP prescriptions of being so diluted that they are unlikely to benefit biodiversity (Pe'er et al., 2014). Thus, it is critical to evaluate actual CAP measures from a biodiversity conservation perspective. Empirical evaluations are challenging, if not infeasible, as they would require large scale and long term monitoring of abundance and distribution for a wide range of species, landscapes, and eco-regions and for the implementation of different EFA types. We therefore demonstrate here that well-tested mechanistic simulation systems are suitable for assessing the effectiveness of EFAs.

In particular, agent-based models (ABM) are ideally suited to this task as they simulate how the structure and dynamics of complex systems emerge from first principles such as adaptive behaviour and energy budgets (Grimm et al., 2005; Grimm and Berger, 2016). They combine physiological and behavioural processes at the individual level with demographic processes at the population level (Railsback and Grimm, 2012). Comprehensive agent-based simulation models can take landscape features, including farming practices into account, and can represent the social-ecological processes necessary to understand management and policy implications relevant to agricultural systems (Malawska et al., 2014; Malawska and Topping, 2016). Importantly, they can represent existing expert knowledge and are rich enough in their structure and mechanisms to be evaluated and validated simultaneously at different levels of organisation and different scales (Grimm et al., 2005; Augusiak et al., 2014).

As a promising and well-established example of a simulation system, we used the spatially explicit agent-based Animal, Landscape and Man Simulation System (ALMaSS) (Topping et al., 2003). ALMaSS represents real landscapes and farming practices in great detail and at a high spatial and temporal resolution, and has been used to predict population dynamics and the consequences of different landscape structures and pesticide applications for a wide range of species. ALMaSS has been in use and under development since 1998 and includes a hare model (Topping et al., 2010b). The hare model is well tested (Topping et al., 2010b) and fully documented using an extended version of the ODD protocol for describing agent-based models (Grimm et al., 2006, 2010), which combines software for documenting program code with the rationale of ODD (ALMaSS Model Documentation, 2014). The resulting ODDox documentation is a hypertext which is openly available on the internet (http://www2.dmu.dk/ALMaSS/ODDox/ALMaSS_ODDox/V1_02/index.html). A range of population control parameters was evaluated using "pattern-oriented modelling" (Wiegand et al., 2004; Grimm et al., 2005). Model testing followed "the modelling cycle" (Railsback and Grimm, 2012), which is an iterative process whereby models are tested against carefully selected performance criteria (Topping et al., 2010b; Augusiak et al., 2014). Moreover, the generation of the Danish landscapes and implementation into ALMaSS is described in detail in Topping et al. (2016). Therefore, as the model has already been documented and tested comprehensively, we here will use it as a given "virtual laboratory" and restrict tests and model analyses to the features we added in the definition of the agricultural landscapes.

To demonstrate the potential of ALMaSS and similar modelling systems in general for evaluating CAP measures, we used the case of the European brown hare (*Lepus europaeus* PALLAS, 1778). The brown hare has been in widespread decline throughout Europe since the 1960s (Flux and Angermann, 1990; Homolka and Zima, 1999; Edwards et al., 2000; Smith et al., 2005; Smith and Johnston, 2008). Although present across a wide geographic range, the brown hare is listed under Appendix III of the Bern Convention in Europe (Smith and Johnston, 2008), and several countries have placed the species on their Red List as "near threatened" or "threatened" (Reichlin et al., 2006). Located in the European cultural landscape, the hare is a typical example of many other open farmland species in Europe (e.g., European hamster, Eurasian skylark and Grey partridge) that are affected by agricultural intensification and its side effects (Donald et al., 2001; Stoate et al., 2001). Having an average home range of more than 20 ha depending on the landscape type (Schai-Braun and Hackländer, 2014), the brown hare is an excellent species to examine agricultural changes in a larger section of landscape and across fields.

Numerous studies show that monocausal explanations of hare population dynamics are not possible (Marboutin et al., 2003; Schmidt et al., 2004; Smith et al., 2005). Thus, assessments and evaluations of hare population trends are difficult to perform due to the interactions that occur between multiple stressors and the spatial and temporal variability in field data (Smith et al., 2005; Topping et al., 2010b). Furthermore there is still a lack of long-term and large-scale population data, despite extensive observation efforts in recent decades (Strauss et al., 2008). To understand the ecological significance of agricultural effects on hare populations, habitat use must be examined precisely in space and time (Rühe and Hohmann, 2004; Smith et al., 2004; Strauss et al., 2008). In the present study, we use ALMaSS for this task.

In this study, we assessed the benefits of several EFA types for the brown hare. Specifically, we addressed the following research questions: (1) How do hare populations respond to an increased proportion of several EFA types in the landscape? (2) Are these enlarged EFA sites sufficient for hares to achieve viable population densities? (3) Are there qualitative differences between the effects of different EFA types regarding hare population dynamics? As the population density of hares fluctuates enormously at a local scale and depends on many external factors, previously published reports provide only very few reliable numbers. Homolka & Zima (1999) estimated that typical densities of stable hare populations in Europe range from 20 to 70 individuals per km^2. Based on this estimation we set our long-term viability criterion for this study at 10 females per km^2.

To answer our research questions, EFAs that are assumed to be relevant to the brown hare were selected according to the EU Regulation No 1307/2013 (Article 45, 46) and Delegated Regulation (EU) No 639/2014 (Article 45). We implemented seven greening scenarios in which the cover of the following EFA types was increased to 5% of the whole agricultural area: cultivation of nitrogen-fixing crops such as (1) peas and (2) beans, (3) permanent and (4) rotational set-asides, (5) permanent extensive grasslands, and (5) herbaceous and (6) herbaceous and (7) woody field margins. We expected all greening scenarios to lead to higher hare abundances but also expected noticeable differences between their effects. For example, one might assume that areas such as set-asides or grasslands would be more beneficial as they provide larger contiguous habitats for hares than do narrow field margins. Likewise, permanent measures, such as long-term set-asides, might be more effective than temporary measures, such as rotational set-asides, as they provide year round food sources and cover. However, quantitatively verifying and accurately predicting these effects without a detailed, mechanistic models seems impossible.

2. Methods

2.1. Landscape simulation system

ALMaSS was developed as a predictive analytics tool to answer policy questions regarding the effect of land-use change on different key animal species (Topping et al., 2003). Therefore, the model combines agent-based animal models with a detailed and dynamic