MODELLING OF HOME RANGE DYNAMICS FOR THE ESTIMATION OF POPULATION-LEVEL IMPACTS IN AN INDIVDIUAL-BASED MODEL OF THE COMMON SHREW (*Sorex araneus*)

Magnus Wang[1] and Volker Grimm[2]

[1] RIFCON GmbH, Im Neuenheimer Feld 517, D-69120 Heidelberg, Germany
[2] Helmholtz Centre for Environmental Research, UFZ, Permoserstr. 15, D-04318 Leipzig, Germany

Abstract

Probabilistic models have recently been introduced into risk assessment methodology for plant protection products, which marks a first step into a scientific evaluation of effects, their probability and magnitude. When it is probable that an effect occurs, the next logical step in risk analysis is to evaluate which impact that effect might have on local populations of focal species. Population models are one method for evaluating population effects (e.g. recovery times). The requirements for such models are high, they have to realistically reflect many aspects of the population ecology of a species, e.g. population dynamics, population regulation, or the spatial distribution of the animals. In the case of vertebrates, home range behaviour is particularly relevant, not only for the spatial behaviour but also for population regulation. Most territorial animals show marked home range dynamics, depending on food resources and the presence of conspecifics. Though home range dynamics are an important aspect of population regulation, most existing population models assume no or static home ranges. We therefore present a population model for the common shrew which describes home range dynamics on a daily time scale. The proximate purpose of the model is to realistically capture home range and population dynamics. The ultimate purpose is to develop a model that can be used for evaluating population effects after application of plant protection products.

Introduction

Home ranges, and defended territories in particular, have a strong impact on population density and dynamics. At low density, all individuals of a population may establish territories of sufficient size and reproduce, while at high density only some individuals are able to monopolize a sufficiently large area and are able to breed. Additionally, home ranges may be moved from one habitat to another, e.g. from arable fields to surrounding habitats, according to the attractiveness of the habitats. In order to use population models in conservation biology or risk assessment of plant protection products, it is essential to model the spatial distribution of the animals and population regulation explicitly, which implies that home range dynamics have to be considered.

We therefore present a model which is one of the first ones explicitly describing home range dynamics and their consequences for population regulation and the spatial distribution of the animals (Wang and Grimm 2007). As a model organism we use the common shrew (*Sorex araneus*), a common insectivore in a variety of habitats, including grass-land, woodland, arable land, and hedges.

Methods

An individual-based model was developed, which simulates the behaviour of each distinct individual in a population in order to predict the development of the entire population. The model uses landscapes, represented as a grid of hexagonal cells. Each cell contains a given amount of food which changes seasonally. Individuals have several state variables, such as gender or age, and they possess a home range. The values of the model parameters were obtained from the literature. Some uncertain parameters were refined by calibration.

Home range are represented by a number of cells in the landscape used by an individual (figure 1). Each day shrews optimise their home range, i.e. they try to obtain their food from the smallest possible area, which is done by adding the cells with the highest amount of food to the home range and by releasing the cells with the lowest amount of food.

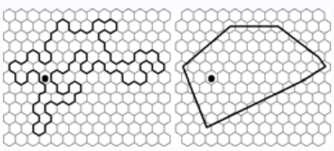

Figure 1. The home range of a shrew in the individual-based model (left: cell-representation; right: minimum convex polygon home range).

Results

Model testing

Reproduction, survival, population dynamics and the spatial distribution of the animals were analysed and compared with field observations from the literature. (table 1). In a mixed habitat structure (hedges, cereal fields, grassland) animals concentrated in habitats with the highest amount of food (hedges, grassland, see figure 2). Animals in low-food habitats showed markedly increased home ranges.

Figure 2. Spatial distribution of common shrew home ranges in a simulation in a mixed habitat structure.

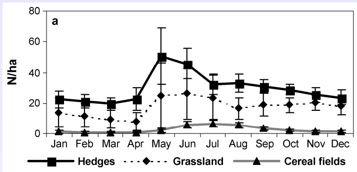

Figure 3. Common shrew population densities in a simulation in mixed habitat structure.

Densities in the habitat hedges, cereal fields and grassland (figure 3) were similar to those reported in the literature. Home ranges decreased at high density while dispersal increased (figure 4). Since only resident shrew reproduce, dispersal regulated population density. The model's ability to reproduce population regulation was tested by artificially increasing or decreasing population size at the beginning of the breeding season. Populations recovered from changes of up to 10 (increase) to up to 20 percent (decrease) within one breeding season (figure 5).

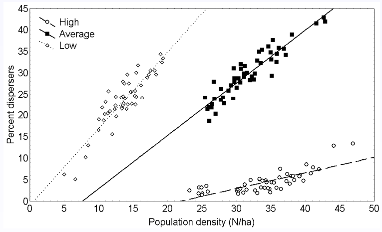

Figure 4. Dependence of dispersal on population density and food abundance. Dispersal increases at high population density and low food abundance.

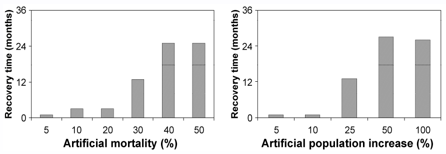

Figure 5. Time until recovery after artificial population decrease (left) and increase (right) of common shrew populations in grassland. Population were assumed to have recovered when density was not significantly different compared to unmanipulated populations (Mann-Whitney U test).

Sensitivity analysis

Population size showed the highest sensitivity to parameters of female reproduction, i.e. start (β_i = -0.631) and end of the breeding season (β_i = 0.135), female mortality (β_i = -0.381), litter size (β_i = 0.339), and gestation length (β_i = -0.327). These results are in concurrence with the biology of the species.

Variables for model validation of	Model output	Literature values	References
Reproduction			
Litters per female lifetime	2	1-2	Churchfield (1990)
Percentage of pregnant or lactating females	82.6-100%	up to 90% and more	Churchfield (1990)
Age distribution at the begin of the population increase (% juveniles & subadults)	1st mon.: 39.7% 2ndmon.: 74.4% 3rdmon.: 85.3%	1st mon.: 35.8% 2ndmon.: 63.2% 3rdmon.: 84.4%	Calculated from Churchfield et al. (1995)
Survival			
Survival rates	Mon. rate/mon. 1-2 0.784 3-13 0.914 ≥14 0.544	Mon. rate/mon.[1] 1-2 0.645 3-13 0.850 ≥14 0.333	Churchfield et al. (1995)
Life spans	max 15 mon.	max 15 mon.	Churchfield (1990)
Age distributions	see above	see above	see above
Spatial distribution			
Home range sizes	Subad.: 490 m² Males: 2361m² Females: 1027m²	Subad.: 526 m² - -	Michielsen (1966) No references for adult *S. araneus* , but 2x and 4x increase reported for ♀♀ and ♂♂ *S. vagrans* (Haw es, 1977)
Percentage of dispersers	up to 35	-	-
Population dynamics			
Timing of population peak	Jun-Aug	May-Sept.	Michielsen (1966); Churchfield, (1980); Churchfield, et al. (1997)
Fluctuations of max. density	-72.1 to +109.6%	-38.6 to +118.5%	Michielsen (1966); Pernetta (1977); Churchfield (1980); Churchfield et al. (1995 and 1997)
Fluctuations of min. density	-50.0 to +120.0%	-77.4 to +173.2%	
Age distributions	see above	see above	see above

Table 1. Prediction of the individual-based model compared to field observations from the literature ([1] Survival rates from the literature are minimum survival rates).

Conclusions

The model reproduces the major characteristics of common shrew ecology, e.g. home range dynamics, habitat preference, and density dependent dispersal. Population densities and dynamics were approximately equal to those reported from field studies. Hence, the model fulfils the prerequisites for application in risk assessment, i.e. the ability to reproduce the spatial behaviour, population dynamics and population regulation.

We conclude that the basic design of our model is also applicable for other species showing a marked home range behaviour, and that a realistic representation of population regulation might require explicit modelling of home range behaviour.

Published in Ecological Modelling:
Wang, M., Grimm, V. 2007. Home range dynamics and population regulation: An individual-based model of the common shrew Sorex araneus. Ecol. Modelling, in press.

References

Chuchfield, S., Hollier, J., Brown, V.K., 1995. Population dynamics and survivorship patterns in the common shrew, *Sorex araneus*, in southern England. Acta Theriol. 40, 53–68.

Churchfield, S., 1980. Population dynamics and the seasonal fluctuations in numbers of the Common shrew in Britain. Acta Theriol. 25, 415–424.

Churchfield, S., 1990. The Natural History of Shrews. Christopher Help, London.

Churchfield, S., Hollier, J., Brown, V.K., 1997. Community structure and habitat use of small mammals in grasslands of different successional age. J. Zool. Lond. 242, 519–530.

Hawes, M.L., 1977. Home range, territoriality and ecological separation in sympatric shrews, *Sorex vagrans* and *Sorex obscurus*. J. Mammal. 58, 354–367.

Michielsen, N.C., 1966. Intraspecific and interspecific competition in the shrews *Sorex araneus* L. and *S. minutus* L. Arch. Neerlandaises Zool. 17, 73–174.

Pernetta, J.C., 1977. Population ecology of British shrews in grassland. Acta Theriol. 22, 279–296.

Wang, M., Grimm, V. 2007. Home range dynamics and population regulation: An individual-based model of the common shrew *Sorex araneus*. Ecol. Modelling, in press.