POPULATION DYNAMICS AND MANAGEMENT OF Sus scrofa IN WESTERN SWITZERLAND: A STATISTICAL MODELLING APPROACH

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Abstract: In Western Switzerland as in other parts of Europe, the high densities of *Sus scrofa* have serious economic consequences for agriculture. In order to improve management actions and reduce impacts, we have undertaken a time series analysis on factors that may explain the increasing abundance of wild boars and have made stochastic simulations of population dynamics to assess the impact of management by hunting. Over a 32 years period, we show that the expansion of maize cultures explains 49.7% of the variance in the numbers of wild boars annually shot and is thus one of the main factors controlling population growth. Since the amounts of boars taken by hunting can be shown to be proportional to boar populations, we use the data furnished by hunters to calculate survival rates and fecundities for three age classes (0-1 year, 1-2 years, > 2 years) and simulate population dynamics using the RAMAS/age stochastic model for age structured populations. Density dependence parameters are also estimated from hunting data. The stochastic model produces fairly realistic predictions and simulations can be used to compare harvesting strategies. The statistical modelling approach presented in this paper is limited by the quality of parameter estimation, and, in the case of the stochastic population model, by its strong sensitivity to variations in density dependence parameters. However, qualitative predictions and risk assessments can be made, providing a very useful tool for the improvement of Wild boar management.

Keywords: Wild boar, *Sus scrofa,* Suidae, Stochastic population model, Management strategies.

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1. Introduction

In Switzerland, as in other parts of Europe, the Wild boar *Sus scrofa* may nowadays be considered as a problematic species because of the serious economic impact it has on agriculture. This impact is a consequence of the population increase that has been observed throughout Europe (Saez-Royuela & Telleria, 1986) and the simultaneous difficulty to control populations efficiently by hunting, at least in Western Switzerland. In order to contribute to the improvement of Wild boar management, this paper first examines the effects of a few general environmental and landscape variables on population size over a 32 years period (1960-1991). Then, using data collected from hunting statistics, stochastic simulations of population dynamics are made to explore and assess the impact of different management strategies.

2. Material and methods

A basic assumption in this work is that the amount of boars killed each year by hunting is proportional to population size. To test this hypothesis, the number of boars killed per year by hunting has been compared with Wild boar damage records, standardised per area unit of maize fields actually planted. Since standardised damages should be proportional to population size (see Baettig, 1988) and since the regression analysis shows a reasonable degree of explained variance (R^2 = 0.61, $p < 0.001$), it can be concluded that this hypothesis is fairly met by the data.

2.1. Time series analysis of factors influencing population dynamics

A cross-correlation time series analysis (Box & Jenkins, 1976) has been undertaken in order to find whether variables such as the area of maize recorded each year, the mean annual temperature or the mean annual rainfall have an influence on Wild boar numbers (N = number of boars shot per year). Meteorological data have been furnished by the Swiss Meteorological Institute (Zurich), all other data are taken from the annual reports of the Department of Agriculture, Industry and Commerce of the canton de Vaud (Lausanne).

2.2. Stochastic modelling of population dynamics

Using the detailed indications furnished by hunters and a body weight criterion derived from Baettig (*op. cit.*) to separate age classes, life tables including three age classes (0-1 year, 1-2 years, > 2 years) could be constructed for boars in the years 1986-1992 (in the first age class, the number of individuals has been increased by 20% to compensate for the piglets that are not included in hunting statistics). Age specific survival rates, fecundities and their coefficients of variation have also been estimated from these data. Following the method given by Burgman *et al.* (1993) it has also been possible, by regression of the realised growth rate against N, to obtain a rough estimate of density dependence parameters for the Ricker equation, using the formula:

$$\ln \frac{(N_{t+1})}{N_t} = r - ßN_t$$

were r is the rate of increase and ß a measure of the strength of density dependence. Using all these demographic parameters, population dynamics could be modelled using the RAMAS/age stochastic model for age structured populations (Ferson & Akçakaya, 1990).

3. Results

3.1. Time series analysis

A simple look at the graphical data (Fig.1) suggests a relationship between the area of maize planted and N, the number of boars. The cross-correlation time series analysis actually shows that N is best explained by the square root of maize area planted two years before (time lag - 2: $R^2 = 0.497$) and by the mean annual temperature recorded two years before (time lag - 2: $R^2 = 0.288$). When these two variables are combined into a multiple regression analysis, the level of explained variance attains $R^2 = 0.599$ ($p < 0.001$), *i.e.* 59.9 %.

3.2. Stochastic modelling of population dynamics

The demographic parameters used for the simulation of populations dynamics with RAMAS/age are given in Table 1. The Ricker function parameters using the regression method are r = 0.709 and ß = -0.005 ($R^2 = 0.329$, p = 0.01). Using these parameters and an initial population size of 500 (0-1 year: 225, 1-2 years: 140, > 2 years : 135), the simulations produce a stable population after a few years of runtime (as in figure 2 A). In practice, taking ß = - 0.001 gives more realistic results, the population of 500 remaining at a stable level. To compare different management strategies, this modelled population has been submitted to different hunting strategies, all based on an additional harvest of 10% of the initial population size each year. These 50 harvested individuals have been distributed in various harvesting combinations over the three age classes. The results obtained for the different management strategies are not given in detail here but are illustrated by selected results of a second set of simulations (Fig. 2) that was made with exactly the same data except for the survival rate of age class 1 for which a value of 0.5, closer to values observed in other studies (Gaillard *et al.*, 1987), was taken. Qualitatively, the population dynamics did not differ between the first and second set of simulations.

4. Discussion

The results presented here suggest that hunting data may be used to analyse population dynamics and improve management. This supports previous results obtained by Badia *et al.* (1991), who have clearly shown how detailed hunting data can be used to estimate population size.
The indication that maize cultures strongly influences Wild boar populations is not a surprise and quantitatively confirms the intuition of many wildlife managers in Switzerland. The two years time lag suggests that maize has a positive influence on female fitness and reproductive success, that translates into an increase of young boars shot in their second year of life.
The use of demographic parameters estimated from hunting statistics to perform stochastic

Table 1. Mean demographic parameters used for *Sus scrofa* (Years : 1986-1992, n = 7; mean sex ratio: 42 % of females). The parameters have been estimated from hunting data (see text). CV = coefficient of variation.

Age class	% of N	Fecundity	CV	Survival	CV
0	45	2.17	0.113	0.547	0.225
1	28	5.12	0.113	0.906	0.061
2	27	6.23	0.113	0.20	0.061

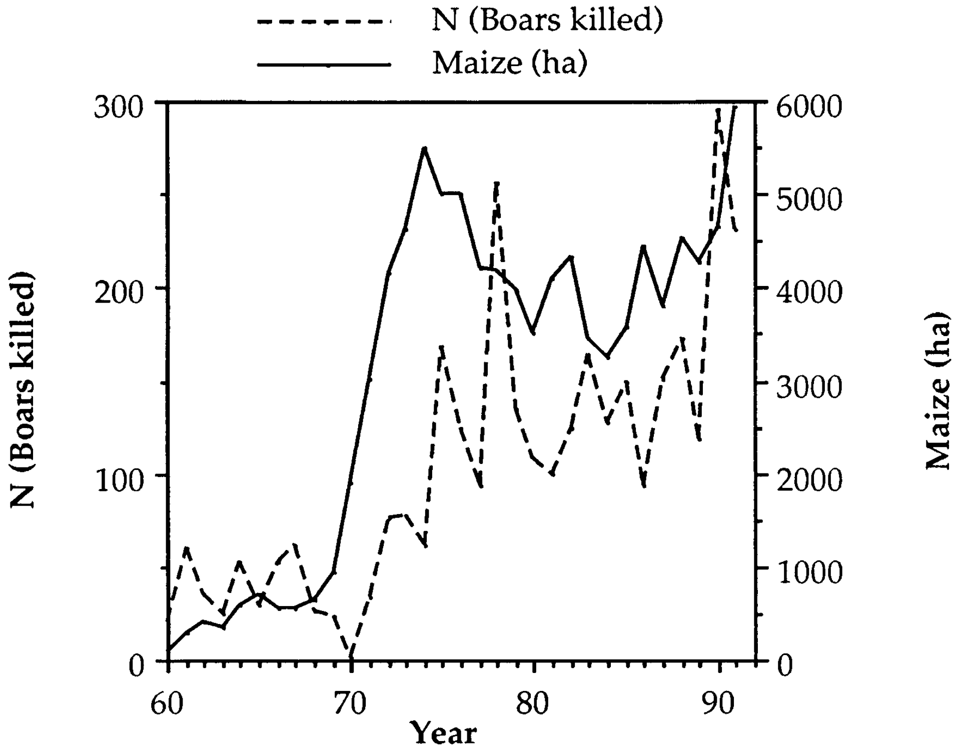

Figure 1. Variation of the number of boars killed by hunting (N) and of the area of maize planted in the Canton de Vaud (Switzerland) between 1960 and 1991.

population simulations shows that although such an approach may be expected to be biased in several ways, the values obtained for survival and fertility do not strongly differ from values obtained by other authors, *e.g.* Gaillard *et al.* (*op. cit.*), Spitz (1989) and Gerard *et al.* (1991). The two statistical modelling approaches presented in this paper are certainly limited by the quality of parameter estimation. In the case of the time series analysis, although very rough and general data were used, fairly predictive results could be obtained on the factors controlling population dynamics. Thus, with better data, one might be able to obtain a precise estimation of the influence of environmental and landscape factors on the Wild boar population dynamics. In the case of the stochastic population model, the results are even more dependent on parameter estimation. The strong sensitivity of the model to variations in density dependence parameters is a classical problem (Burgman *et al.*, 1993). However, the fact that qualitative predictions and risk assessments can be made is encouraging because even if quantitative predictions are unlikely to be made, the RAMAS/age model provides a very useful tool for comparing Wild boar management strategies. This model could be improved for wildlife managers by adding a possibility to make more investigations on harvesting effects, *e.g.* by including a function to produce the emigration of relative proportions of each age class rather than constant and absolute numbers of migrating individuals each year.

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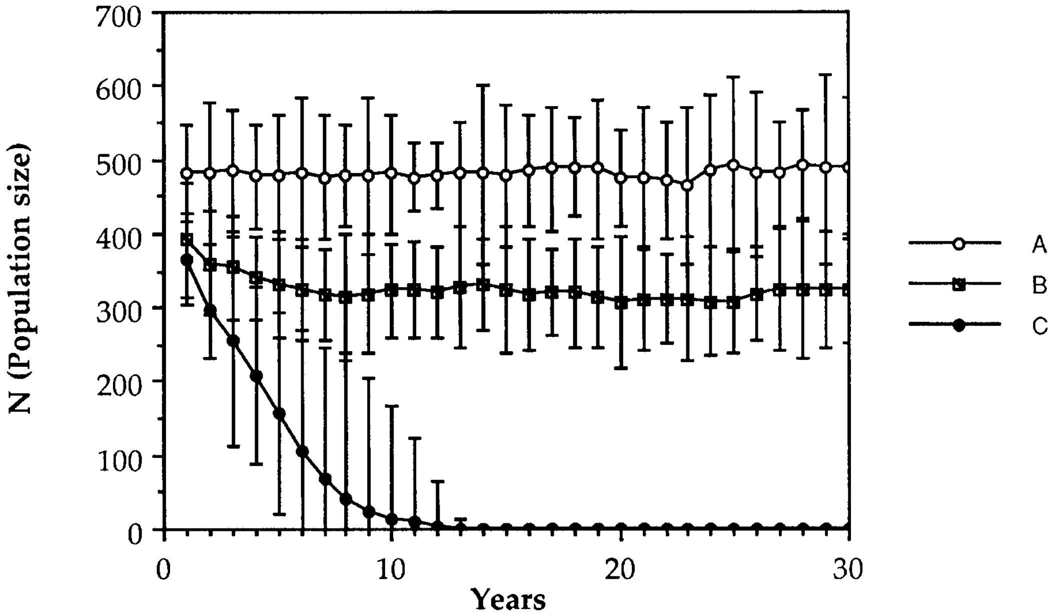

Figure 2. Three population trajectories simulated using RAMAS/age. A. Without additional hunting. B. With selective additional hunting of 50 individuals per year in the age class 2. C. With selective additional hunting of 25 individuals in age class 0 and 25 individuals in age class 1. Error bars are 95 % confidence intervals for population size estimates.

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