METHODS OF POPULATION ESTIMATES OF A HUNTED WILD BOAR (Sus scrofa L.*) POPULATION IN TUSCANY (ITALY)*

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Abstract: On the basis of demographic data on 1253 wild boars hunted in Monticiano (Siena) from 1984 to 1991, age, sex and life tables were computed. Demographic parameters in combination with hunting effort provided the basic data to check the population trends year by year. Estimates of the population were computed through 9 different methods which fall into three general classes (Catch per Unit Effort, Population Reconstruction, Lang and Wood's Pennsylvania method). An evaluation of these methods is provided.

Keywords: Wild boar, *Sus scrofa,* Suidae, Population estimates.

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1. Introduction

An important source of information on wildlife populations is often the hunters' harvest and a variety of techniques and methods has been developed to analyse these data. Several techniques of analysis should always be tested and evaluated using a population of known composition and size. As an alternative a population should be monitored over a long period of time, using independent methods and data sets (Roseberry & Woolf, 1991). We present here different techniques which were applied to the study of a Wild boar population over a seven years period. A combination of demographic parameters and data on hunting effort and success provided the basic input data (Boitani *et al.*, this volume).

2. Methods

Demographic data of 1253 wild boars hunted in Monticiano (Siena, Italy) from 1984 to 1991 were used to compute age, sex and life tables (Boitani *et al.*, *op. cit.*). Wild boars are hunted by driving them against a line of posted hunters. Traditionally, hunting occurs three times a week from November to January. Hunting effort is significant (about 1,000 hunters afield per a total 30 days), rather constant and uniformly distributed on the 4,840 ha study area. Estimates of the population trend were calculated using nine different methods: these are grouped for similarity of inputs and assumptions into 3 classes (following Roseberry & Woolf, *op. cit.*):

1) CATCH PER UNIT EFFORT

The ratio of animals caught to effort expended is proportional to the number of animals in the population at the beginning of capture period (N). The primary variable influencing the number of wild boars killed is the number of individuals in the population; in fact hunting, the major cause of mortality during winter, takes a random (and therefore representative) sample of the living population. A basic assumption is that the population must be closed between capture/killing events: in our area we can accept the assumption as immigration equals emigration and very few births occur at that time of the year (Boitani *et al.*, *op. cit.*). Probability of capture between November and January remains constant (except for little individual variations due to behavioural and/or physiological reasons), as hunters do not operate any significant selection on wild boars. Zero to five months old piglets are rarely killed because of hunting tradition and the difficulties in catching them.

- *Catch Method* (Zippin, 1956). When two catches (C_1; C_2) are taken with equal effort, population size prior to the first catch (first half of hunting season) can be estimated as: $N=C_1^2/(C_1-C_2)$.

- *Leslie Method* (Leslie & Davis, 1939). Catch per unit of effort (y) plotted against the previous cumulative catches (x) provides a straight line cutting the x-axis at the population size prior to harvesting (Caughley, 1977). If the trend of the points is not linear (as in our case) the method should be abandoned.

- *Direct Index* (Eberhardt, 1960). The catch per unit effort (C) is a function of population size and can therefore serve as an index to the latter. Mathematically this method states: C(t) = K · N(t), where K = constant, N = catchability (total catch/ hunters)

- *De Lury Method* (De Lury, 1947). Log of catch per unit effort is a linear function of cumulative effort. Eberhardt (*op. cit.*) modified De Lury's (1951) exponential equation to estimate prehunt population size: $N = C/1 - (e^{-cE})$, where C = total catch, c = proportion of population caught per unit of effort, and E = total effort. Each unit of effort (1,000 hunters or 100 days hunted) was assumed to take on average 18-20% of the living population each year: these percentages were determined by trial and error and the obtained values of "c" were tested against reconstruction population results to check for minimum population homology.

2) POPULATION RECONSTRUCTION

Numbers of animals dying in each sex and age class are required for at least two subsequent years. As the basic input is harvest data, *i.e.* only a portion of winter total deaths, reconstruction represents only a portion of the living animals. In our sample the annual cohort harvest was relatively constant in time, as the annual kill was proportional to the living population. Age determination was accurate up to the age of 3 years, for older animals a potential error can occur (Boitani *et al.*, *op. cit.*).

- *Standard reconstruction* (Fry, 1949). The minimum possible number of animals alive in a given cohort for a given year is determined summing all the individuals from that cohort retrieved in subsequent years. For cohorts not completely passed throughout the year/population matrix, the proportion of the population harvested per unit of effort (based on previous reconstruction and harvest data) in combination with current harvest and effort estimates is used to obtain pre-hunt population size (Fryxell *et al.*, 1988). Alternatively, an average harvest rate from previous reconstruction and harvest is computed and divided into current harvests (Creed *et al.*, 1984).

- *Downing Method* (Downing, 1980). Similar to the previous one, this technique computes survival rates by the number of dead animals in the last inclusive age category, instead of arbitrarily proportioning this class into older ones. These rates and the number of dead animals in these classes are used to estimate numbers alive at the beginning of the year. Younger age classes are reconstructed by simple addition.

- *Cohort Analysis* (Fryxell *et al.*, *op. cit.*). This method combines Cohort analysis or Reconstruction with the Catch per unit effort method. For cohorts passed through the population (1984, 1985, 1986), estimates of age-specific mortality are used to compute past abundance. For recent years (1987, 1988, 1989, 1990) a vulnerability coefficient *q* (proportion of population killed per unit of effort) is estimated for each cohort using the average of data from several past years: $q = \log_e\{(\text{reconstruction-harvest})/\text{reconstruction}\}/\ \text{effort}$. Following Vassant *et al.* (1988) and Spitz *et al.* (1984), average harvest mortality rate is 80%, and age-specific survival rates are assumed to decrease with increasing age.

- *Winsconsin Method* (Creed *et al.*, *op. cit.*). Minimum population estimate for males (TM) is obtained by Standard Reconstruction of annual harvest data. TM, multiplied by an expansion factor (EF = a measure of adult sex ratio), gives estimate of total population size (TP). When years are too recent to be included in the reconstruction, TM is estimated by dividing the male harvest for that year by the average of male harvest rates in the previous 3-years (obtained by dividing actual harvest by TM for that year).

3) LANG AND WOOD'S PENNSYLVANIA METHOD (Lang and Wood, 1976)

The average annual reduction rate (AARR) for adult males is computed from the male harvest age structure (following Downing, *op. cit.*):

$AARR = 1 - \{(H2.5+H{\geq}3.5)/(H1.5+H2.5+H{\geq}3.5)\}$

where H1.5, H2.5, ≥H3.5 = number of hunted wild boars 1.5, 2.5 and ≥3.5 years old respectively. Adult male harvest is divided by AARR to obtain pre-hunt adult male population. Adult-female:adult-male ratio (FA/MA) is computed using Severinghaus and Maguire's technique (1955) and multiplied by the female-fetus:male-fetus ratio to adjust for possible unequal recruitment into the yearling class. Pre-hunt adult male population is multiplied by FA/MA to obtain pre-hunt adult female population. Piglets: adult females ratio (P/FA) is computed by harvest data. Estimated pre-hunt adult female population is then multiplied by P/FA to give piglets crop. The sum of adult males, adult females and piglets gives total pre-hunt population.

COMPARATIVE EVALUATION OF TECHNIQUES

When more than one estimates were obtained from each technique, the chi-square test of homogeneity was run and the confidence limits computed. A comparative evaluation of the results obtained by the different methods was tested using the χ^2 test of homogeneity (to analyse the annual variability among estimates) and the variance test (to check for trend similarities among results obtained from each technique).

3. Results and discussion

Our results (Tab. 1) are not absolute population estimates, as information on crippling losses, natural mortality and piglets younger than 6 months were missing. However, estimates are comparable, as all were biased in the same direction. In order to obtain statistical significance some values were excluded from the averages (Tab. 1).

Out of nine methods, only eight gave acceptable estimates: our data did not fit the Leslie method assumptions (*i.e.*, the series of catches must have decreasing values).

χ^2 and variance tests show that the different estimates are reasonably homogeneous: results can then be lumped to track a final population trend over time (Fig. 2). All methods, although slightly different in numbers, show similar fluctuations of the population: a peak in 1985, a low in 1988, followed by a new peak. The only discrepancy is in 1986-87 trends, when the *Cohort Analysis* and the *Downing Method* are the only methods showing a decrease (Fig. 1f and 1e). The former is probably justified by arbitrarily selected non-harvest mortality rates, while no explanation, other than sampling bias, was found for the second technique's disagreement.

As stated by Roseberry and Woolf (*op. cit.*), *Catch per unit effort* variations (Fig. 1a, 1b,1c) offer a useful tool to monitor population estimates with limited input data, while *Population Reconstruction* models (Fig. 1d, 1e, 1f, 1g) are appealing because of their underlying simplicity and logic, although they are sensitive to changes of the numbers of harvested boars. When such fluctuations reflect changes in harvest intensity rather than population size, trends will be biased. A constant fraction of all deaths is needed in order to carry out a minimum reconstruction. This requirement may be violated by any change in hunting regulations during the study period, and also by weather or other conditions affecting hunting success. Minimum reconstruction is expected to perform best when hunting is the principal cause of death, as harvest is relatively easy to measure and the remaining deaths may not be numerous enough to significantly increase the size of the reconstructed population. However, the relative importance of the harvest can not be evaluated until the other causes of death have been measured at least once. *Lang and Wood* method was the most difficult to compute for its mathematical requirements and appears to be less sensitive, precise and robust than the previous ones (Roseberry & Woolf, *op. cit.*).

4. Acknowledgements

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Table 1: Population estimates using eight different methods.

METHOD	1984	1985	1986	1987	1988	1989	1990
Catch Method	444	515	482	493	327	487	620
Direct Index	487	527	425	453	328	469	602
De Lury Method	414	573	480	477	294	473	573
Standard Reconstruction	407	560	451	462	[262]	[393]	525
Downing Method	420	518	486	476	365	519	596
Cohort Analysis	451	[471]	466	430	334	503	561
Winsconsin Method	440	510	482	497	[276]	430	551
Land and Wood Method	441	587	442	495	[397]	516	617
AVERAGE	**438**	**541**	**464**	**473**	**330**	**485**	**581**
± SE	±22	±29	±19	±20	±31	±29	±28

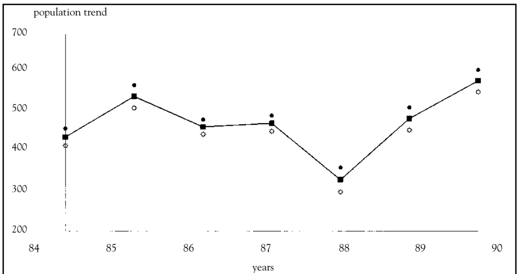

Figure 2 - Population trend using average estimates of Tab 1.

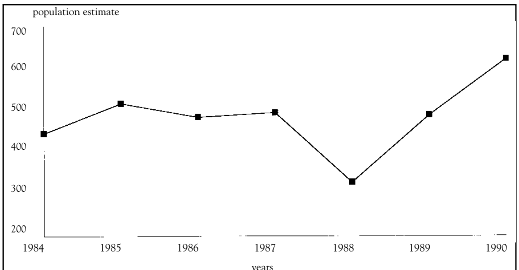

Figure 1a - Catch method trend

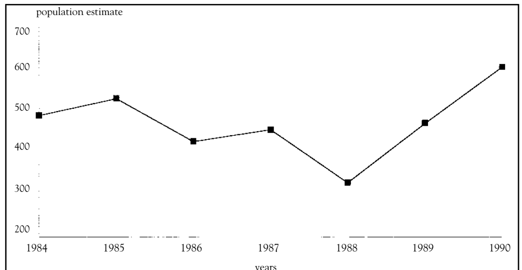

Figure 1b - Direct index trend

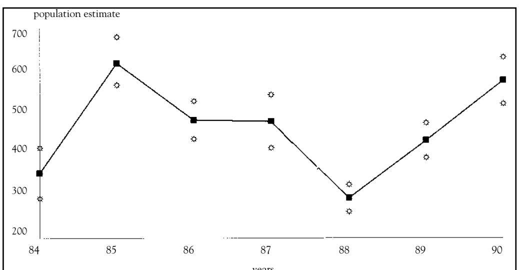

Figure 1c - De Lury method trend

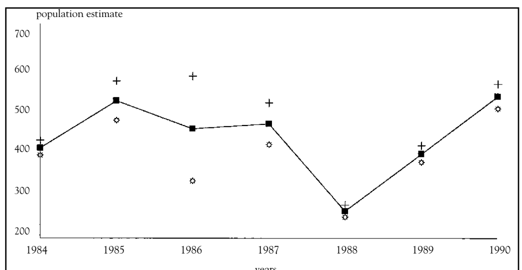

Figure 1d - Standard reconstruction trend

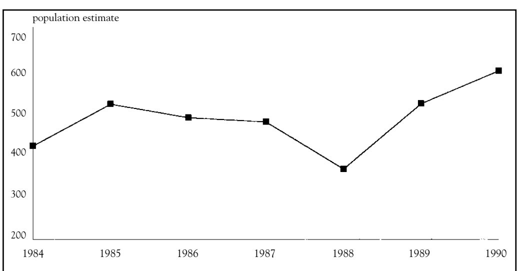

Figure 1e - Downing method trend

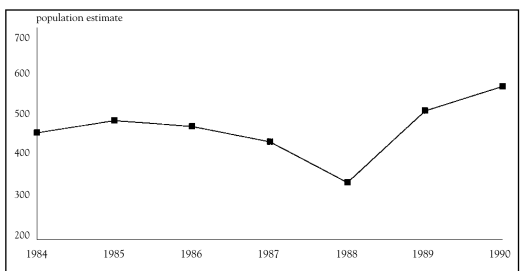

Figure 1f - Cohort analysis trend

Figure 1g - Winsconsin method trend

Figure 1h - Lang and Wood method trend

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