



Annual survival rates of adult male Corsican Nuthatches *Sitta whiteheadi*

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The endemic Corsican Nuthatch *Sitta whiteheadi* population is small and currently restricted to mountain forests of Corsican Pine *Pinus nigra laricio*. An estimate of annual survival rate is an important parameter to allow evaluation of extinction risk. Adult Corsican Nuthatches were colour-ringed and resighted on territory in the Ascu Valley, central Corsica, from 1998 to 2005. Mark-recapture methods were used to estimate the annual apparent survival rate of male Corsican Nuthatches as 0.616 (95% CI 0.524–0.700), the best model being independent of time. The longest lifespan recorded for any individual was five years and seven months. During the study, there was no strong evidence that annual survival was affected by the variation in a key food source, Corsican Pine seeds.

The Corsican Nuthatch *Sitta whiteheadi* is endemic to Corsica in the western Mediterranean (42°N, 9°E). Its range is currently restricted to the mountain forests where the Corsican Pine *Pinus nigra laricio*, an endemic subspecies of the European Black Pine, is its main habitat. The Corsican Nuthatch population is very small (less than 2,500 pairs), and its suitable habitat – mature Corsican Pine forest – is currently restricted to less than 15,000 ha (J.-C. Thibault, unpublished data). It inhabits mature stands with tall, larger trees, and avoids younger stands. Adults appear to be strictly sedentary and males defend their territories all year round (Thibault *et al* 2006).

During the breeding season, Corsican Nuthatches eat arthropods (Villard *et al* 2003), whereas from late autumn to early spring pine seeds constitute an important, if not virtually exclusive, component of the diet (Thibault *et al* 2002). Cone crop is related to tree age, with older trees producing more cones. Corsican Nuthatches select their territories in mature stands where the number of cones has been estimated as several thousands per hectare during years of good production (Moneglia 2003), representing a large potential food resource. However, cone production varies annually, and this variation affects timing of breeding of the nuthatches: earlier breeding occurs when the number of cones available during the previous winter was greater (Thibault & Villard 2005). To investigate further this close link between pine-cone production and nuthatch ecology, we studied the potential influence of cone production on the annual survival rates of adult Corsican Nuthatches.

MATERIALS AND METHODS

Study site and monitoring

From 1998 to 2005, field work was conducted in April and May in a Corsican Pine forest (Forêt communale d'Ascu) located in the central part of the island, at an altitude ranging from 1,000 to 1,600 m. The study site covered c 90 ha. Territorial adults were caught with mist nets set under the forest canopy (from ground level up to 8 m) and colour-ringed. Birds were lured with recorded calls. Colour-ringed individuals were resighted on territory in subsequent years using binoculars (10 x 42). To estimate variation in cone production, we used binoculars to count the number of unripe cones per pine on the ten Corsican Pines (diameter at chest height ≥ 20 cm) nearest to a tree containing a Corsican Nuthatch nest site which was occupied during the previous breeding season. The number of unripe cones was counted, before they opened and released their seeds, on 12 to 16 territories (depending on the year) from September to November in each year from 2000 to 2004.

Survival analyses

To estimate adult survival, we used Cormack–Jolly–Seber (CJS) models (Lebreton *et al* 1992). We tested the full CJS model with time-dependent survival (ϕ_t) and recapture (resighting) probabilities (p_t), for goodness-of-fit using the U-CARE software (Choquet *et al* 2005a).

To test the main effects of different factors and their interactions we used the M-SURGE software (Choquet *et al* 2004, 2005b). To select the most appropriate model we used the Akaike Information Criterion (AIC_c) corrected for the effective sample size (Lebreton *et al* 1992): $AIC_c = DEV + 2k + 2k\{n/(n-k-1)\}$, where DEV represents

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the deviance $[-2\ln(L)]$, L the likelihood of the model evaluated at maximum likelihood estimates, k the number of separately estimable parameters in the model, and n the effective sample size. The models were ranked using the difference between the AIC_c of the model and the AIC_c of the best model (referred to as ΔAIC_c). ΔAIC_c can be interpreted according to this scale: models having $\Delta AIC_c \leq 2$ are strongly plausible, those where $4 \leq \Delta AIC_c \leq 7$ are considerably less plausible whereas models having $\Delta AIC_c \geq 10$ are improbable (Burnham & Anderson 2002).

We used the mean number of cones per pine tree in each year to evaluate the impact of cone production on adult survival. To assess the effects of cone production, we followed methodology devised by V. Grobois *et al* (unpublished data). First, we assessed the magnitude of the variation unexplained by this covariate by a likelihood ratio test between models with time dependent survival (φ_t) and with a covariate effect on survival ($\varphi_{\text{covariate}}$). Because unexplained variation was undetected (likelihood ratio test (LRT) $\varphi_{\text{covariate}}/\varphi_t$, $\chi^2_6 = 6.8$, $P = 0.34$), and the best model supposed constant adult survival (see Results), we tested the effect of covariate using a likelihood ratio test between models with constant survival (φ) and with a covariate effect on survival ($\varphi_{\text{covariate}}$). We also estimated the proportion of explained variation in survival or resighting probabilities accounted for by the covariate (R^2), calculated as

$[\text{DEV}(M_{\text{covariate}}) - \text{DEV}(M)] / [\text{DEV}(M_t) - \text{DEV}(M)]$, where DEV was the deviance for survival models with covariate, constant, and time effects, respectively.

RESULTS

Survival and resighting probability

More males than females were ringed owing to their strong territorial behaviour. Therefore, in the present analysis we have taken into account only the total of 64 marked

Table 1. Summary matrix of the adult Corsican Nuthatch data set. The first column indicates the number of birds released at each occasion, columns 2 to 8 indicate the number of survivors first resighted at a given occasion i , conditional on the number of birds released at the previous occasion $i-1$, and the last column represents the total number of survivors first resighted.

| | | | | | | | | |
|----|---|----|---|---|----|---|---|----|
| 8 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 27 | | 14 | 0 | 0 | 1 | 0 | 0 | 15 |
| 17 | | | 9 | 0 | 0 | 0 | 0 | 9 |
| 18 | | | | 9 | 0 | 0 | 0 | 9 |
| 17 | | | | | 11 | 0 | 0 | 11 |
| 15 | | | | | | 8 | 1 | 9 |
| 16 | | | | | | | 9 | 9 |

males. The M array summary matrix is given in Table 1. The CJS model fitted the data correctly (Test 2 + Test 3, $\chi^2_{10} = 9$, $P = 0.53$). The models tested are compared in Table 2. The best model among those time-dependent or constant survival and/or resighting probabilities was that with both constant annual survival and resighting probabilities (φ, p). The estimates from this model are $\varphi = 0.616$ (95% CI 0.524–0.700) and $p = 0.897$ (95% CI 0.760–0.960). The longest recorded lifetime between ringing and last resighting (adult male) during the study was five years and seven months.

Effect of cone production

Table 3 indicates the numbers of unripe cones counted each year. No statistically-significant effect of variation in annual cone production on survival was detected (LRT $\varphi/\varphi_{\text{covariate}}$, $\chi^2_1 = 3.6$, $P = 0.06$, $R^2 = 19\%$, slope (not significant): 0.67, 95% CI -0.78 to 2.12).

DISCUSSION

The probability of resighting male Corsican Nuthatches was high, as expected for a species showing a high degree of territory fidelity and with an annual territory reoccupation rate of greater than 90% (Thibault & Villard 2005). When compared to several congeners, the Corsican Nuthatch shows a relatively high survival rate and a relatively low clutch size (Table 4). For these nuthatch species, survival rate seems to be more closely related (negatively) to fecundity than to morphometric characters (eg body mass) (see Ghalambor & Martin 2000).

Table 2. List of models obtained. The best and most parsimonious model is indicated in bold. ΔAIC_c stands for the difference between AIC_c of the best model and the model considered.

| Models | Deviance | Parameters | ΔAIC_c |
|---------------------------------|---------------|------------|----------------|
| φ, p | 189.99 | 2 | 0 |
| φ_t, p | 185.62 | 8 | 7.6 |
| φ_t, p_t | 182.41 | 13 | 14.4 |
| $\varphi_{\text{covariate}}, p$ | 189.18 | 4 | 3.2 |

Table 3. Number of unripe cones counted in autumn, from 2000 to 2004.

| Year | Mean cones per tree | Standard deviation | Number of trees |
|------|---------------------|--------------------|-----------------|
| 2000 | 19 | 36.4 | 160 |
| 2001 | 121 | 114.6 | 120 |
| 2002 | 103 | 160.3 | 142 |
| 2003 | 100 | 136 | 110 |
| 2004 | 7 | 14.9 | 150 |

Table 4. Comparative demographic data on nuthatches (\pm indicates standard deviation).

| Species | Body mass (g) | Mean clutch size | Location | Annual survival | References |
|---|-------------------------|-----------------------------|---------------|--|---|
| Corsican Nuthatch <i>Sitta whiteheadi</i> | 12.1 \pm 0.48, n=87 | 5.1 \pm 0.50, n=21 | Corsica | 0.62 (0.52–0.70) \pm 0.045, n=64 (males) | Thibault & Villard 2005, this work |
| Brown-headed Nuthatch <i>S. pusilla</i> | 10.3, n=35 | 5.1 \pm 0.91, n=369 | USA | 0.54 ("theoretical annual survival rate" of both sexes together) | Withgott & Smith 1998 |
| White-breasted Nuthatch <i>S. carolinensis</i> | 21.1 \pm 2.2, n=266 | 7.3 | Maryland, USA | 0.35 \pm 0.01, n=32 (both sexes together) | Karr <i>et al</i> 1990, Pravosudov & Grubb 1993 |
| | | | Arizona, USA | 0.12 \pm 0.06, n=33 | |
| Red-breasted Nuthatch <i>S. canadensis</i> | 9.8 \pm 0.7, n=310 | usually 6 over its range | Arizona | 0.46 \pm 0.19 to 0.87 \pm 0.33, n=196 (both sexes together) | Ghalambor & Martin 1999, 2000 |
| European Nuthatch <i>S. europaea</i> | 23.4, n=75 (Belgium) | 6 to 8 over its range | Belgium | 0.55, 0.59 (males) | Matthysen 1998 |
| | | | Sweden | 0.46, 0.51 (males) | |
| | | | Poland | 0.54 (males) | |
| | | | Siberia | 0.65 (males) | |

We did not detect any statistically significant effect of Corsican Pine cone production on the annual survival of the Corsican Nuthatch. Although cone production can vary greatly from year to year (Debazac 1991; P. Moneglia, pers comm), there appears always to be a minimum of production, with some scattered trees producing cones, sometimes in great number (P. Moneglia, pers comm). This suggests that Corsican Nuthatches can typically find enough seeds to eat and to hoard on their own territories or in the vicinity through the winter. Furthermore, this suggests that food availability is unlikely to represent a limiting factor during this period. Habitat selection for territories with large trees, usually producing large numbers of cones (Thibault *et al* 2006), could be so strong that it allows the birds to be sedentary, whatever the variation of the cone crop. However, as the sample size is low, the statistical power to detect annual variation in resighting probability or an effect of a covariate on survival is also low. Therefore, further monitoring studies are needed to explore the effects on survival of temporal variation in cone crop and other environmental factors.

An estimate of annual survival rate is an important parameter, in conjunction with data on productivity and population size, to allow evaluation of extinction risk (Beissinger & Westphal 1998). Good understanding of population dynamics is particularly important in this case as nuthatches have been subject to a relatively high extinction rates compared to other bird genera (Bennett & Owens 2002) and Corsican Nuthatches have decreased

in number due to habitat loss from fire and wood-cutting (J.-C. Thibault, unpubl. data).

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