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its suitable habitat – mature Corsican Pine forest – is currently restricted to less than 15,000 ha (J.-C. Thibault, unpublished data).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 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 (\( \phi_t \)) 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):

\[
AIC_c = \text{DEV} + 2k + 2k[\ln(n/(n-k-1))]
\]

where DEV represents...
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 AICc of the model and the AICc of the best model (referred to as \(\Delta\text{AICc}\)). \(\Delta\text{AICc}\) can be interpreted according to this scale: models having \(\Delta\text{AICc} \leq 2\) are strongly plausible, those where \(4 \leq \Delta\text{AICc} \leq 7\) are considerably less plausible whereas models having \(\Delta\text{AICc} \geq 10\) 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 (\(\phi_t\)) and with a covariate effect on survival (\(\phi_{\text{covariate}}\)). Because unexplained variation was undetected (likelihood ratio test (LRT) \(\phi_{\text{covariate}}/\phi_t, \chi^2_6 = 6.8, P = 0.34\), 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 (\(\phi\)) and with a covariate effect on survival (\(\phi_{\text{covariate}}\)). We also estimated the proportion of explained variation in survival or resighting probabilities accounted for by the covariate (\(R^2\)), calculated as

\[
\text{DEV}(M_{\text{covariate}}) - \text{DEV}(M) / \text{DEV}(M) - \text{DEV}(M_{\text{covariate}}),
\]

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 males. The M array summary matrix is given in Table 1. The CJS model fitted the data correctly (Test 2 + Test 3, \(\chi^2_9 = 9, P = 0.53\)). 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 (\(\phi, p\)). The estimates from this model are \(\phi = 0.616\) (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 \(\phi/\phi_{\text{covariate}}, \chi^2_1 = 3.6, P = 0.06, R^2 = 19\%\), 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 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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean cones per tree</th>
<th>Standard deviation</th>
<th>Number of trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>19</td>
<td>36.4</td>
<td>160</td>
</tr>
<tr>
<td>2001</td>
<td>121</td>
<td>114.6</td>
<td>120</td>
</tr>
<tr>
<td>2002</td>
<td>103</td>
<td>160.3</td>
<td>142</td>
</tr>
<tr>
<td>2003</td>
<td>100</td>
<td>136</td>
<td>110</td>
</tr>
<tr>
<td>2004</td>
<td>7</td>
<td>14.9</td>
<td>150</td>
</tr>
</tbody>
</table>

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 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.

A Table 4. Comparative demographic data on nuthatches (± indicates standard deviation).

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

ACKNOWLEDGEMENTS

Thanks are due to Elena Bulmer, Jane Davidson, Aurélie Dréville, Jean-François Seguin, Pascal Villard and Carolyne Wheat for help with the fieldwork, to Pasquale Moneglia for communication of unpublished data, and to Alice Cibois, Guy Anderson and an anonymous referee for improving previous drafts of the manuscript. This study was a “Personnel program” of the Centre de Recherches sur la Biologie des Populations d’Oiseaux (Paris) and it has been granted by the Direction de l’Environnement de Corse (Ministry of Environment).

REFERENCES


© 2006 British Trust for Ornithology, Ringing & Migration, 23, 85-88

(MS received 3 April 2006; MS accepted 27 June 2006)