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Massive immigration balances high anthropogenic mortality in a stable eagle owl population: Lessons for conservation

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ABSTRACT

The modern anthropized landscape is a major source of hazards for large animals such as raptors. Collisions with cables, vehicles and trains, as well as electrocution cause casualties, which may negatively impact populations. Yet, demographic studies of that impact remain scarce, which is an impediment to evidence-based conservation action. We studied the dynamics of an eagle owl (*Bubo bubo*) population in the northwestern Alps (Switzerland). We estimated, firstly, its demographic parameters using a Bayesian integrated population model; secondly, the frequency of different types of casualty through radio-tracking. Thirdly, we investigated the effects of reductions of human-related mortality on population trends. The breeding population was small but remained fairly stable during 20 years, suggesting that it was apparently in a good shape. However, survival probabilities of all age classes were very low ($\leqslant 0.61$), productivity fairly good (0.93), and immigration very high (1.6 females per pair and year), indicating that the population operated as a sink. Half of the mortality was caused by infrastructure, with electrocution accounting for 24% of all fatalities. The elimination of electrocution would result in a strong population increase (17% annually). Under that scenario, immigration rate could decline by 60% and the population would still remain stable. Given that the supply of recruits from elsewhere is likely to continue, we can expect a rapid local population recovery if dangerous electric pylons are mitigated systematically. Our study demonstrates that detailed demographic analyses are necessary to diagnose problems occurring in populations and to identify efficient conservation actions.

1. Introduction

Small populations face a higher extinction risk than large populations (Lande, 1993). Even populations that remain stable during a long time may have a high risk of extinction. They may function as sinks, being able to maintain an apparent stable demography although this is only due to recurrent immigration. Thus, their continued existence depends on other populations. To diagnose such latent vulnerability of small, non-declining populations we need a specific analytical framework, essentially because targeted conservation options may substantially differ depending on the underlying demographic status and structure of a population. This calls for sophisticated analytical demographic tools such as integrated population modelling (Besbeas et al., 2002; Brooks et al., 2004; Schaub et al., 2007).

The modern landscape is characterized by dense infrastructure networks such as railways, motorways, electric power lines or wind turbines, to mention but a few. Infrastructure not only impacts landscapes, it also represents a source of danger for many animal species. Collisions with vehicles and aerial cables, and electrocution on dangerous pylons are major causes of casualties among animals (Schaub and Pradel, 2004). Such human-related mortality may actually have a considerable impact on populations, yet empirical studies remain scarce (Sergio et al., 2004). Understanding the relative impact of these sources of mortality on population dynamics requires unbiased estimates of the frequency of the mortality causes (Schaub, 2009), an assessment of whether the mortality cause considered is fully additive to the remaining mortality (Schaub and Lebreton, 2004), as well as the construction of a demographic model to evaluate whether a reduction in a focal mortality cause may improve the demography of the study population.

The eagle owl (*Bubo bubo*) is a nocturnal bird of prey that is widespread in Europe. In Western Europe, a marked decline took place until the 1980s, but several areas have been progressively

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re-colonised afterwards, which is due either to massive release programmes (e.g. Germany, Bergerhausen et al., 1981) or natural re-colonisation from core distribution areas (e.g. Rhône valley in France, Cochet, 2006). The Swiss population of eagle owls has also decreased strongly over the past decades, but there have been signs indicating slight recoveries in many areas recently. Yet, a major characteristic of the Swiss and other nearby eagle owl populations seems to be a highly intermittent occupancy of traditional breeding sites with frequent disappearance of territorial adults which are replaced only slowly (Sergio et al., 2004; Cochet, 2006; Ortego, 2007). This turn-over is unusual for a long-lived species and seems to coincide with local casualties: adult eagle owls are often victims of electrocution and traffic accidents in the close vicinity of breeding sites which are then temporarily abandoned (Sergio et al., 2004). Delgado and Penteriani (2005) have shown that an insufficient number of individuals in the floater segment of a population may destabilize species population dynamics and site occupancy, affecting overall reproductive performance. However, the impact on eagle owl demography of the mortality induced by the artificialization of the landscape through infrastructure networks remains unclear.

We investigated the population dynamics of a small eagle owl population inhabiting a large Alpine valley in southwestern Switzerland (Arlettaz, 1988). This population is demographically open although the valley is enclosed within very high mountain ranges (Aebischer et al., 2010). We first estimate demographic rates (age-specific survival, fecundity, immigration) from different types of data (radio-tracking, population surveys, number of fledglings, age-at-death ratio). We base our population diagnosis on a single coherent Bayesian integrated population model (Besbeas et al., 2002; Brooks et al., 2004; Schaub et al., 2007). This powerful framework allows determining whether a local population is a sink (population growth rate <1 in the absence of immigration) or a source. Secondly, we estimate the relative importance of various mortality sources with respect to age classes using a sample of locally radio-tagged owls. Finally, we use our population model to investigate what-if scenarios to gauge the demographic response of the population if human-related mortality could be completely or partially removed. Our study provides the necessary strategic guidance for developing efficient and yet pragmatic conservation policies for eagle owl populations and other large raptors facing similar threats in the modern landscape.

2. Methods

2.1. Data collection

The study was conducted in the upper bottom of the Rhone valley in the southwestern Swiss Alps (Canton of Valais: 46.1–46.4°N; 6.8–8.9°E) from 1988 to 2008. The study area was 1–6 km wide and about 105 km long. It is flanked by high mountain ridges above 3000–4000 m altitude. The plain is characterized by intensive agriculture and dense human settlement. Numerous roads, railways, channelized rivers and powerlines cross the plain. Eagle owls mostly breed in cliffs adjacent to the valley bottom where they hunt preferably (Nyffeler, 2004).

We collected three different types of data from Valais eagle owls. Firstly, the study area was prospected annually to count the number of breeding pairs. This was done mostly by visiting formerly occupied breeding sites and potentially suitable sites during the courtship period, either at dusk or dawn, to locate singing adults (Arlettaz, 1988). Secondly, we counted annually the number of fledglings which were located through their characteristic begging calls and/or with the use of telescopes, binoculars, spotlights or night devices. Thirdly, we radio-equipped 41 young eagle owls at nest of which 28 were tracked after they left their parents in 2002–2008 (Aebischer et al., 2010). Twenty-one of these young were equipped with 30 g, battery-powered satellite transmitters (lifespan: 6.5–8.5 months) and 20 young with 15 g VHF-tags (lifespan: 32 months) (for information about suppliers, see Aebischer et al., 2010). However, young equipped with satellite tags also wore a conventional VHF-tag. All VHF-tags were fitted with an activity sensor. The young stemmed from 23 different broods at 10 sites. We checked tagged birds at least once every fortnight within an area of about 11,000 km^2 covering Valais and some adjacent regions.

Another data set consisted of all eagle owls found dead throughout Switzerland from 1988 to 2008. A questionnaire was sent to most Swiss cantonal hunting and fishery services, bird rescue centres and museums of natural history. We inquired about the number of eagle owls found dead by any given institution, about date and location of finding. For 102 individuals (skins and stuffed birds) age-at-death could be determined based on plumage pattern, whilst cause of death could be assessed from 117 eagle owls. The sample was restricted to free-ranging, wild birds. Captive-reared eagle owls that were released in the course of reintroduction programmes, and were systematically ringed, were not considered as their mortality pattern may differ substantially from that of wild-born birds (Bezzel and Schöpf, 1986).

2.2. Estimation of demographic parameters

We used an integrated population model (Besbeas et al., 2002; Brooks et al., 2004; Schaub et al., 2007) to estimate survival, immigration, fecundity and population size from the above described different sources of demographic data (population surveys, number of fledglings, radio-tracked young, age-at-death data). A major advantage of an integrated population model is that all data sets are analysed within a single model simultaneously, which allows to estimate demographic parameters for which no explicit data are sampled (immigration in our case) and to get more precise parameter estimates (Abadi et al., 2010a). We fitted the integrated model in the Bayesian framework as it provides more flexibility than the frequentist framework (Brooks et al., 2004; Schaub et al., 2007) and exact measures of parameter uncertainty (Link and Barker, 2010). Next we describe the likelihoods of the demographic data and then show how they are integrated into a single model.

2.3. Likelihood for radio-tracking data

We considered the tracking data (T) obtained from the 28 tagged young after they had left their parents to estimate apparent survival during the first year of life (see Aebischer et al. (2010) for details on data sampling). Although all tagged individuals were checked at least once every second week, some could not be located at a given occasion although it was *a posteriori* clear that they were still alive in the study area. We had thus to use capture-recapture methods (Lebreton et al., 1992) to estimate survival corrected for detection. When the tag batteries failed before the owls reached 1 year of age, the corresponding birds were treated as censored at last encounter. That is, only the period of their life history between tagging and battery exhaustion was considered for the estimation of survival. Some tagged owls died before reaching 1 year of age and they might have been retrieved. We assumed that the probability to reencounter an individual alive in the survey area was higher when that individual had already been detected at the preceding occasion (trap-happiness effect). Based on these data, we constructed a multistate capture-recapture model with the three stages (“alive and encountered”, “alive but not encountered” and “dead”) to estimate apparent juvenile survival (ϕ_{juv}: