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Waterbird demography as indicator of wetland health: The French-wintering common snipe population

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ABSTRACT

The population dynamics of waterbirds constitute an indicator of wetland conservation status. However, waterbird population censuses are difficult to implement because the individuals are very mobile within their range, and some species are elusive or breed in remote areas. Therefore, demographic models based on the estimation of survival and breeding success appear as a reliable alternative to population censuses. Here we present this model-based approach in the case of the French-wintering snipe population (*Gallinago gallinago*), which breeds mainly in Northern and Eastern Europe. Using a multi-state model to accommodate the mobile nature of waterbirds, we estimate snipe survival using a joint analysis of capture–recapture and ring-recovery data. Then, we use matrix population models to estimate the minimum recruitment rate required to maintain the population at its current size and derive a chart for using age-ratio of ringed birds as indicator of population trend. Although we call for more data collection in order to reduce uncertainty, we conclude that occasional declines are likely after years with poor breeding success, but that the French-wintering snipe population is on average stable. Individual-based monitoring data and population modeling make it possible to use waterbirds as indicator species at the flyway scale.

1. Introduction

Wetland degradation (drainage and pollution) is one of the first consequences of landscape anthropization (Baldock, 1984). Yet wetlands provide ecosystem services that are essential to our societies (denitrification, flood water retention, etc.; Gleason et al., 2008); thus wetland preservation represents a major conservation challenge (Ramsar-Convention-Secretariat, 2010). A distinctive suite of birds are specialized on wetlands and need them to breed, roost and feed. These birds can be used as indicator species for the conservation status of the wetlands that correspond to their species-specific habitat requirements. For example, the assemblage of species that use reedbeds depend on water levels and reed harvesting (Graveland, 1999; Barbraud et al., 2002; Polak et al., 2008); see also Davidson and Stroud (2006), DeLuca et al. (2008), Paillisson et al. (2002). Several historically abundant species are currently among the fastest declining species in the world (Amano et al., 2010; Greenberg et al., 2011), suggesting that wetland degradation can jeopardize even common species' survival. Here we focus on a particularly widespread European waterbird, Common snipe *Gallinago gallinago* (snipe hereafter). Snipes inhabit all types of freshwater marshes, migrate on a broad front, and are not restricted to coastal areas as are most other waders that winter in Europe. A large part of the northern and eastern European population winters in France, making the French-wintering population an indicator of wetland health along this flyway (Dodman and Boere, 2010). Recent trends from some breeding population surveys are currently raising concerns for this species (BirdLife-International, 2012). In addition, snipe is a gamebird with a French hunting bag reaching 250,000–300,000 birds annually (Tesson and Leray, 2000). This hunting bag has decreased recently, further suggesting population decline. A proper quantification of the European snipe population dynamics thereby appears necessary to inform the status of this indicator species. This quantification can also be used to aid decision-making about sustainable hunting.

Large-scale population censuses yet remain very challenging in snipes as in most other waders (Amano et al., 2010; Davidson and Stroud, 2006), because of the large breeding and wintering ranges that encompass remote areas, of the long-range migrations and of the short-term response to fluctuations in water levels. Snipes further challenge field biologists because of their elusive nature.

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Therefore, process-based population models that separate the demographic processes of survival, fecundity, and movement constitute reliable alternatives to pattern-based models based on population censuses (Beissinger and Westphal, 1998). To document survival probability and harvest rates, a nation-wide ringing program has been set in place in recent years in France (starting during the 1999/2000 hunting season). Recaptures of live birds and recoveries of dead birds have been recorded, which provide information about the survival of snipes that winter in France. These data are typically analyzed using capture–recapture–recovery models (e.g., Gauthier and Lebreton, 2008). Snipe behavior, however, challenges typical assumptions of capture–recapture–recovery models. Although snipes do exhibit site-fidelity both within and across winters when the conditions allow (Davies, 1977; Spence, 1988), when the conditions are unfavorable (droughts, floods, and freezing conditions) they undertake within-winter movements that are similar to nomadism; they track water levels and avoid areas that become unsuitable. This is a behavior typical to most waterbirds, including ducks (Roshier et al., 2002), gulls (McNichols, 1975), and raptors (Martin et al., 2006). From a modeling standpoint, both recapture and recovery probabilities are influenced by this behavior: snipes that exit the area where they were ringed are unlikely to land in another ringing area, and will thus not be subject to recapture anymore. Snipe hunting is more evenly distributed across space, so that snipes that escape recapture by ringers may still be reported by hunters. To address that issue, we designed multistate capture recapture models (Lebreton et al., 2009) that allowed marked individuals to transit between a state "In ringing area" subject to recapture and a state "Out of ringing area" not subject to recapture. By doing so, we estimated survival while accounting for possible movements of individuals between these states. Hereafter we describe this model and its implementation. Then we use matrix population models to discuss the implication of our data and findings for the characterization of snipe population trend.

2. Materials and methods

2.1. Field procedures and data selection

Two methods of capture were used. Most snipes were caught with mist-nets at dawn or dusk in marshes or meadows. The remaining records were obtained during daytime with traps placed along the water line of ponds or in intensively used feeding sites. Age determination (hatch year bird or adult) was made after examination of wing and tail feathers (CICB and OMPO, 2002; Wlodarczyk et al., 2008). A total of 10,721 snipes were ringed between 1999 and 2011, of which 563 were recaptured later and 584 were recovered by hunters. From this extensive dataset we selected the records corresponding to birds ringed between November and February, i.e., we excluded birds most likely to still be migrating. We also excluded recaptures occurring outside of this period. We discarded records when the age at ringing was not recorded (c. 250 records) as well as records from the Mediterranean region (c. 200 records) because many of these birds came from a more southerly flyway (breeding areas in central Europe). This selection yielded a final dataset containing records from 4029 snipes (1420 ringed as adults, 2609 ringed as hatch-year birds). Of these, 113 were recovered by hunters and 150 were recaptured at least once during a hunting season different from the season during which they were ringed. The maximum number of encounters per individual was 3. Annual survival probability was estimated from November 1st to October 31st the following year. The 12 month period starting on November 1st following the birth of an individual is hereafter termed its "Hatch year".

2.2. Goodness of fit tests

We tested the goodness of fit of the Cormack–Jolly–Seber model (Lebreton et al., 1992) to the recapture data only (not the recovery data). We used the "overall test" in software U-CARE (Choquet et al., 2009a) for that purpose. This test can be divided into components (Pradel et al., 2005). Among these components, the test for short-term transience (component 3.SR testing for a difference in encounter probability between previously captured and newly-marked snipes) and the test for short-term trap-dependence (component 2.CT testing for a difference in the probability to be encountered in hunting season $t+1$ between the snipes captured during season t and those not captured that season), when they are both significant, suggest individual or spatial heterogeneity in recapture probability (Péron et al., 2010). Such heterogeneity would for example be expected if ringed snipes were a mixture of migrants and resident wintering birds.

2.3. Multistate capture–recapture–recovery model: general structure

Based on our understanding of snipe movement behavior, we considered two "live" states, namely state 1 "alive and in a ringing area" and state 2 "alive and out of ringing areas". As typically done when combining recapture and recovery data (Gauthier and Lebreton, 2008; Hénaux et al., 2007), these two states were complemented by two "Just dead" states, which represented individuals available for recovery, and a state "Long dead", which represented individuals dead for more than 1 year. The diagram representation of this model is presented in Online Appendix. Each year, birds in state 1 had the probability $1-f_1$ to move to state 2, where f_1 is called state-fidelity; and birds in state 2 had the probability $1-f_2$ to return to state 1. At first capture, all birds were in state 1. Survival probability was denoted S. In matrix notation, this model is represented by the survival-transition matrix Φ of which the (i,j)th cell represents the probability to be in state j at time $t+1$ if in state i at time t:

$$\Phi = \begin{bmatrix} Sf_1 & S(1-f_1) & 1-S & 0 & 0 \\ S(1-f_2) & Sf_2 & 0 & 1-S & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}$$

The model is then fully specified by describing the observation process (Online Appendix). The observation matrix P can also be used for this purpose. It has in its (i,j)th cell the probability to record event j if in state i. Possible events are $j=1$ for "individual not recorded", $j=2$ for "individual captured and alive", and $j=3$ for "individual shot and reported as such":

$$P = \begin{bmatrix} 1-p & p & 0 \\ 1 & 0 & 0 \\ 1-r_1 & 0 & r_1 \\ 1-r_2 & 0 & r_2 \\ 1 & 0 & 0 \end{bmatrix} \tag{2}$$

where p and r denote recapture and (state-dependent) recovery probabilities respectively.

An additional complexity had to be accommodated: ringing occurred throughout a protracted period in winter, and was simultaneous with hunting. Thus, an individual ringed early in the season was exposed to mortality risks for a longer period than an individual ringed late in season. To accommodate that feature we used a monthly formulation of capture–recovery models (Péron et al., 2012a). We denoted $\tilde{s}_w$ the monthly winter survival. For an individual ringed in November, the probability to survive up to the end of