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# Simple assessments of age and spatial population structure can aid conservation of poorly known species

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ABSTRACT

The IUCN Red List is challenged with assessing the conservation status of species on which reliable demographic and distribution parameters are lacking. The hotly debated SAFE index, however, measures the "species' ability to forestall extinction" and only requires information on population size. Nonetheless, both conservation assessment systems neglect the role of non-breeding population fractions in conservation. We conducted simple surveys to ascertain the spatial and population structure and conservation threats of the Endangered red-fronted macaw *Ara rubrogenys*, endemic to the Bolivian Andes. The area of occupancy (ca. 2600 $Km^2$) encompassed eight breeding and six non-breeding areas, occupied by 807 individuals. By combining population-fraction censuses with the proportion of juveniles (8.6%), we inferred a breeding population of less than 100 pairs clumped in 38–40 nesting sites, with non-breeders representing ca. 80% of the population. While this increase in data quality raises questions as to whether the species should be upgraded to Critically Endangered, the SAFE index rendered questionable guidance for conservation triage. Conservation threats were spatially identified according to spatio-temporal and life-stage population structures and seasonal changes in habitat use. Several sources of habitat loss were widespread but, contrary to expectation, habitat-use models indicated that red-fronted macaws were not tied to forest remnants. Instead, they made use of agricultural lands resulting in conflicts with farmers. Awareness campaigns should focus on a few selected locations to resolve this conflict and reduce the uptake of individuals for use as pets, as the most effective way to increase population size in the medium-term.



## 1. Introduction

The IUCN Red List is widely used for policy and conservation planning, even allowing for the estimation of long-term changes in global biodiversity conservation (Butchart et al., 2004). The Red List relies on quantitative criteria for listing species in threat categories, embracing coarse estimates of population size and range distribution of the species and their changes through time (Mace et al., 2008). This system has permitted the evaluation of the conservation status of thousands of species across very different taxa (IUCN, 2012). However, many of them are poorly known species for which gathering population and range estimates is difficult, often because of the inaccessibility of their distribution areas and the spatial biases in ecological studies worldwide (Martin et al., 2012). Thus, 40% of the threatened species of birds, the most studied organisms, were listed on the basis of "poor" quality data (Butchart et al., 2004). In fact, the conservation status of some species dramatically changed when research efforts increased, highlighting the need for feeding high quality data into the Red List process by improving population and range estimates of poorly known species (Tobias and Brightsmith, 2007). This is not however an easy task, given the trade-offs between investing in long-term studies to obtain accurate population and spatial parameters and the time lost in carrying out such studies prior to identifying adequate conservation actions in species that are being driven to extinction. Field work designs that optimize time input while capturing key population and distribution parameters are thus needed to deal with this trade-off and advance on the actual conservation threats of poorly known species. This would avoid wasting monitoring efforts (McDonald-Madden et al., 2010) and the application of management practices based upon dogmatic ideas, which often leads to unexpected results and the bad allocation of economic resources (Martínez-Abraín and Oro, 2013).

Population size, defined by IUCN as the number of mature individuals capable of reproduction (excluding those that will not produce new recruits), is a basic parameter used by several IUCN criteria to score the threat status of species (Mace et al., 2008;

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IUCN, 2013). The use of this parameter underlies the concept of minimum viable effective population size ($N_e$), taken as 50 individuals to avoid inbreeding depression and as 500 individuals to maintain the evolutionary potential of the species (Mace et al., 2008; Jamieson and Allendorf, 2012). Therefore, an overall population ($N_c$) of 5000 individuals would be required to prevent the loss of quantitative genetic variation in a species, a threshold derived from a comparative study across species revealing that the ratio $N_e/N_c$ averaged 0.10 (Frankham, 1995). Recently, Clements et al. (2011) proposed a new system (the SAFE index) to assess the conservation status of species relying only on the difference between overall population size ($N_c$) and an estimated minimum viable population (MVP) of 5000 individuals (Traill et al., 2007). However, both IUCN criteria and the SAFE index neglect to consider that both the proportion of breeders and the $N_e/N_c$ ratio may vary considerably among species (Jamieson and Allendorf, 2012). The number of mature breeding individuals is difficult to estimate for most poorly-known species, and then it is estimated as the proportion of individuals that are mature from the total number of individuals ($N_c$), an approach that often leads to gross overestimates of mature individuals (IUCN, 2013). Moreover, the breeding to non-breeding ratio is expected to be smaller in long-lived species with deferred maturity and longer lifespan (Negro, 2011), and these life history traits greatly vary even among closely related species (Young et al., 2012). Therefore, applying the $N_e/N_c$ ratio or assumed proportions of mature individuals as universal rules may lead to conservation status misclassifications of poorly known species, and thus species-specific estimations are desirable (Flather et al., 2011; Jamieson and Allendorf, 2012).

Distribution range is another key parameter used to evaluate the conservation status of species. The IUCN Red List considers two measures of distribution: the extent of occurrence (EOO), defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of occurrence of a taxon, and the area of occupancy (AOO), defined as the area within the EOO which is actually occupied by the taxon (IUCN, 2013). EOO maps can be obtained by a minimum convex polygon which contains all sites of occurrence (IUCN, 2013) or are hand-drawn by experts based on original records of the species (Jetz et al., 2007). However, these maps are influenced by cases of vagrancy and by marked discontinuities within the overall distribution of a species to the point that most of them greatly overestimate actual range-sizes, especially in the case of narrow-ranging and threatened species (Jetz et al., 2007). Distribution models may help to predict range sizes of poorly-surveyed species, but they project potential distributions (Araújo and Guisan, 2006) and thus are prone to inflate the actual ranges and population sizes of species (Blanco et al., 2012). On the other hand, the AOO may be much smaller and fragmented than the EOO, and thus larger efforts to delimitate distribution are needed at finer scales to assess long-term changes in the conservation status of species (Wilson et al., 2004).

Improving estimations of population and spatial parameters of poorly-known species is not only crucial for a proper conservation status classification, but also for refining and focusing conservation actions especially when resources are limited as in developing countries. Recently, much attention has been paid to the role of the non-breeding fraction on the population dynamics and conservation of species (Penteriani et al., 2011). Threat factors may differentially affect breeding and non-breeding individuals of a population (Oro et al., 2008; Grande et al., 2009), as they may differ in their spatial and/or seasonal patterns of habitat use (Blanco et al., 1998; Penteriani et al., 2011; Tanferna et al., 2013), and threatening factors may even vary at small geographic scales (Carrete et al., 2007). Therefore, any improvement in the knowledge of spatial and population structures would help to design more effective conservation actions while optimizing available resources.

Here, we show how the application of simple and relatively inexpensive surveys can greatly help to estimate population size as well as seasonal and spatial patterns of a poorly-known, globally endangered species. The red-fronted macaw (*Ara rubrogenys*) is endemic to the inter-Andean valleys of Bolivia, inhabiting a tropical dry forest that is considered among the most threatened ecosystems of the world (Miles et al., 2006). The AOO of the species is estimated at 5000 km$^2$, covering three main valleys where it socially breeds in cliffs and feeds on a variety of wild trees (seeds and fruits) and crops (maize and peanuts) (Rojas et al., 2009). Life history traits are typical of a slow-reproducing, long-lived species. Pairs usually raise 1–2 fledglings (Zeballos, 2006; Bonilla, 2007), and data from captivity shows that individuals breed for the first time at a median age of 4.5 yrs, with a maximum lifespan of 36 yrs (Young et al., 2012). Therefore, a large non-breeding population fraction is expected in the wild. Overall population estimates varied from 5000 individuals in the 1980s to 2000–4000 or as few as 700–800 in recent years (Rojas et al., 2009; BirdLife International, 2012). Although these estimates arose from extrapolations of partial censuses (e.g., Lanning, 1991), also lacking information on breeding numbers, the small distribution area and the inferred population decline led to the listing of the species as “Critically Endangered” in Bolivia (Rojas et al., 2009) and as “Endangered” on the IUCN Red List (BirdLife International, 2012). The major threats considered for the species are habitat loss due to agriculture, firewood cutting and overgrazing, wildlife trade, direct persecution as a crop-pest, and the use of pesticides (BirdLife International, 2012). However, no information is available on the relative importance of these threats and how their impacts may vary spatially and between seasons and population fractions. During a two-year period we combined road-side surveys with observation points across the whole distribution of the species, to gain information on population size and structure as well as on seasonal changes in distribution and habitat use. Results rendered the most accurate population and distribution estimates to date, a data-based conservation status category, an age- and spatially-explicit distribution of threats and prioritization of conservation actions, as well as a design for low-cost methodologies for the long-term monitoring of the species.

## 2. Material and methods

### 2.1. Study area

This study covered the whole distribution of the species, restricted to a small area on the east Andean slope of Bolivia (Fig. 1) between Cochabamba, Santa Cruz, Chuquisaca and Potosí, mostly at 1100–2700 m.a.s.l. around the Mizque, Grande and Pilcomayo Rivers. Surveys extended over a wider altitudinal range (500–3500 m) to avoid overlooking previously undetected populations or seasonal altitudinal movements. The habitat is a tropical dry forest which has been transformed by long-term human activities to thorn and cactus scrub with scattered trees and crops (BirdLife International, 2012).

### 2.2. General field work

Data were collected during five surveys conducted in January 2011, April–May 2011, August–September 2011, June 2012 and September 2012. This involved 84 full days of field work by 2–6 people, totaling 247 days/person. To locate red-fronted macaws, we combined roadside transects (3818 km) through the whole study area with observation points at nesting, foraging and