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ARTICLE

Population viability analysis of the Mato Grosso Antbird (*Cercomacra melanaria*) in the Pantanal of Mato Grosso, Brazil

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ABSTRACT: Understanding the interaction between habitat loss, environmental uncertainty, demographic stochasticity and genetics are the goal of population viability analysis. Minimum viable population (MVP) size is an estimate of the number of individuals of a species that will allow the continuation of the population into the foreseeable future. Here, we analyzed the population viability of Mato Grosso Antbird (*Cercomacra melanaria*), an endemic member of the Thamnophilidae from Pantanal, Brazil. We focus on estimating the MVP. We used the program VORTEX to generate simulations for MVP based on demographic and environmental variables, including catastrophes, carrying capacity, reproduction and survival. We also used sensitivity analysis to determine which variables are most influential in viability. We conclude that the Mato Grosso Antbird has low risk of extinction in the next 100 years under current conditions (quasi-extinction probability of 0.002). The MVP of Mato Grosso Antbird was estimated to be 160 individuals. The most influential demographic parameter is the proportion of adult females that reproduce each year. Our results corroborate the classification of the Mato Grosso Antbird as "Least Concern" by IUCN criterion.

KEY-WORDS: endemic passerine, extinction probability, minimum viable population, PVA, Thamnophilidae.

INTRODUCTION

Population viability analysis (PVA) is a mathematical modeling tool that evaluates extinction risk and survival probability over time to direct conservation management (Boyce 1992, Akçakaya & Sjögren-Gulve 2000, Keedwell 2004). This is important, because attempts to conserve small populations are often expensive, difficult, and usually offer only small chances of success (Soulé 1987, Boyce 1992, Keedwell 2004). The minimum viable population (MVP) is the number of individuals that a population should contain to minimize the risk of extinction over a specified time interval (Shaffer 1981, Boyce 1992). MVP is based on estimates of area occupied by the species of interest, its demographic trends and time (Soulé 1987). Habitat loss, environmental uncertainty, demographic stochasticity, genetics (founder effects, genetic drift, inbreeding) and their interactions are the important parameters of a PVA (Shaffer 1981).

Population size is the most important determinant of persistence probability for many species (Diamond *et al.* 1987, Soulé *et al.* 1988, Miller & Lacy 2005). Small populations are very unstable and typically have high extinction probability due to demographic variability (Brito & Grelle 2006). For example, the loss of more than 20 bird species in the Bogor Botanical Garden (Indonesia) was due to small population sizes (Diamond *et al.* 1987). The MVP is also useful in estimating the minimum reserve size that is necessary to the persistence of the species (Grumbine 1990, Reed *et al*. 2002, Leech *et al.* 2008). Information about MVP is very important since habitat fragmentation and loss are key factors influencing the distribution and abundance of threatened species (Lindenmayer & Lacy 2002).

More than one hundred bird species from Pantanal are on threatened species lists (Tubelis & Tomás 2003) and will require some degree of management to secure their persistence (Lindenmayer & Lacy 2002). The main factors associated with bird extinctions are habitat loss, degradation, fragmentation and excessive harvesting

(Marini & Garcia 2005), and more than one of these factors may be affect the population viability (Temple 1986). Fire and prolonged dry season are also factors that can impact the breeding activities of birds (Duca *et al.* 2009, Duca & Marini 2011). The Mato Grosso Antbird (*Cercomacra melanaria*, Thamnophilidae) is the Pantanal's only endemic bird (Silva *et al.* 2001). It was formerly considered as "Vulnerable" and a high priority species for conservation by some authors (*e.g.*, Brown-Jr. 1986, Olson *et al.* 1998, Silva *et al.* 2001), but this species has been evaluated as "Least Concern" since 1988 (BirdLife International 2016). Like most Neotropical bird species, only some aspects of the life history of the Mato Grosso Antbird are known (Pinho *et al.* 2006, Bernardon *et al.* 2014) and therefore more information is required to determine its conservation status in the Pantanal of the Mato Grosso.

The Mato Grosso Antbird is a forest understory insectivore usually found near water, from the Bolivian Chaco and northern Paraguay to the Brazilian Pantanal (Ridgely & Tudor 1994, Sick 1997, Zimmer & Isler 2003, Pinho *et al.* 2006). It is almost always found in pairs in association with vines (*Cissus spinosa, Cissus sicyoides*) and shrubs in seasonally flooded areas (Ridgely & Tudor 1994, Sick 1997, Silva *et al.* 2001, Zimmer & Isler 2003). In this study, we carry out a population viability analysis for the Mato Grosso Antbird. We used simulations to examine persistence probability and the minimum viable population.

METHODS

Study area

The Mato Grosso Antbird was studied in a 100 ha forested area at the Retiro Novo Ranch (16°22'00''S; 56°17'57''W) in the Poconé Pantanal in Mato Grosso state, Brazil. The area is mostly savanna (see Nascimento & Cunha 1989, Cunha & Junk 2001, Arieira & Cunha 2006) and has a cold dry season (April – September) and a warm rainy season (October–March). Average annual temperature is 25.8°C, October is the hottest month (mean 34.0°C) and July is the coldest (mean 16.2°C). Rainfall varies between 1000–1400 mm yr^{-1} (mean 1250 mm.yr^{-1}), 80% of which falls between November–March (Allem & Valls 1987).

Life history attributes of Mato Grosso Antbird

The Mato Grosso Antbird is a monogamous and territorial species, with territories of about 0.32 ha (Bernardon 2007). Clutch size is two eggs and rarely one egg (mean 1.9 eggs), and both sexes begin reproduction at one year old (Pinho *et al.* 2006, Bernardon *et al.* 2014). The maximum-recorded age of a reproducing individual was eight years and mean annual survival was 83% (Nóbrega 2009). Pairs may attempt more than one nest during each breeding season and 50% of females produced at least one offspring each year (Nóbrega 2009). Nest predation is the most important cause of nest failure (68% of failed nests) (Pinho *et al.* 2006). Considering that the breeding season of Mato Grosso Antbird start at the beginning of the rainy season (Pinho *et al.* 2006), we expected that prolonged dry seasons should impact the breeding activities (*e.g.*, Duca *et al.* 2009, Duca & Marini 2011).

Simulation model

Simulations were carried out using the program Vortex v. 9.95, which generates individual-based population models that include deterministic and stochastic processes (demographic, environmental and genetic) (Lacy 2000, Miller & Lacy 2005). The simulations included 500 iterations for each scenario (Chapman *et al.* 2001, Brito & Fonseca 2006, Brito & Grelle 2006) and a 100-year time horizon for population dynamics (Walters *et al.* 2002, Miller & Lacy 2005). Initial population size (2500 individuals) was set at half that of the estimated carrying capacity of the study area (*e.g.*, Brito & Figueiredo 2003, Brito & Fonseca 2006, Brito & Grelle 2006) (Table 1). We assume quasi-extinction when the population size falls below 50 individuals (*e.g.*, Burgman *et al.* 1993) since the extinction probability of such population was high (13%) in the minimum viable population scenario (see section "Minimum Viable Population" below).

Scenarios

Basic scenario: Most data for this scenario come from Nóbrega (2009) (Table 1). For survival estimates, we used data from *Myrmotherula fulviventris* (Thamnophilidae) (Greenberg & Gradwohl 1997) because its survivorship was estimated in a study conducted over 14 years, and this is a well-studied passerine with similar life history to the Mato Grosso Antbird. The consideration of the survivorship from *M. fulviventris* in the basic scenario makes it an optimistic scenario because obligate mixed flock following species typically have higher survivorship than for antbird species feeding alone or in pairs (Jullien & Clobert 2000). The carrying capacity was estimated at 5000 individuals and details about this estimate are available in Nóbrega (2009). Prolonged dry seasons were included as catastrophe (Table 1).

The basic scenario is the one that matches the situation of Mato Grosso Antbird population in the study area, because most of the parameters were developed using data collected there (see Nóbrega 2009). In all scenarios that follow, specific variables were modified to

Table 1. Summary of input parameters of Mato Grosso Antbird, *Cercomacra melanaria*, used in basic scenarios using computer program VORTEX.

Parameters	**Value[Source]**
Reproduction and survival	Correlated[a]
Number/type of catastrophe	1 (long dry season)
Reproduction	Monogamous[b]
Age first reproduction females and males	1[ab]
Maximum reproductive age	8[a]
Maximum young per year	2[ab]
Sex ratio at birth (%)	50[a]
Reproductive females (%)	50.1[a]
Environmental variation in reproduction (%)	9[ab]
Adult males breeding (%)	100[ab]
Number of offspring female^{-1} year^{-1}	Yes
1 young (%)	19[ab]
2 young (%)	81[ab]
First year mortality (%)	23.5[d]
Adult mortality (%)	25[d]
Environmental variation in death rate (%)	11[ab]
Catastrophe	Long dry season
Frequency (%)	10[e]
Impact on reproduction (% reduction)	25[c]
Impact on survival	No
Carrying capacity, *K*	5000[a]
Environmental variation in *K* (%)	100 (2)[c]

Sources: [a] Nóbrega (2009), [b] Bernardon (2007), [c] Duca *et al.* (2009), [d] Greenberg & Gradwohl (1997), [e] INMET (2008).

assess different assumptions about uncertain parameters. All the other variables not specifically mentioned were maintained at their value listed in the basic scenario.

Minimum Viable Population scenario (MVP): to estimate MVP, we changed the initial population size parameter in Vortex and modeled different scenarios with initial population sizes of 1250, 625, 312, 156, 100, and 50 individuals.

Mortality scenario: we reduced the mortality rate from basic scenario to the one found by Nóbrega (2009). Therefore, the annual mortality was reduced from 25% to 17% for adults (≥ 1 year old) and from 23.5% to 15.9% for juveniles (< 1 year old).

Fire scenario: in this scenario we add fire as a second catastrophe. Due to the lack of official fire records in the region, we spoke with residents of the area and estimated this catastrophe with an annual probability of 10%. We assume that the severity of fire results in a 25% reduction in reproductive success. The two catastrophes (fire and prolonged dry seasons) may both cause habitat loss and influence breeding season length, reducing nesting success during the catastrophes.

MVP with two catastrophes: here we estimate MVP with two catastrophes – fire and prolonged dry season. Initial population sizes as above in the MVP scenario.

Sensitivity analysis

Sensitivity analysis was used to test the robustness of some parameters and to assess which parameters have the greatest influence on MVP (*e.g.*, Miller & Lacy 2005, Brito & Fonseca 2006, Duca *et al.* 2009). We changed mortality rates and number of reproductive adults up and down by 10%, 15% and 20% (Fig. 1).

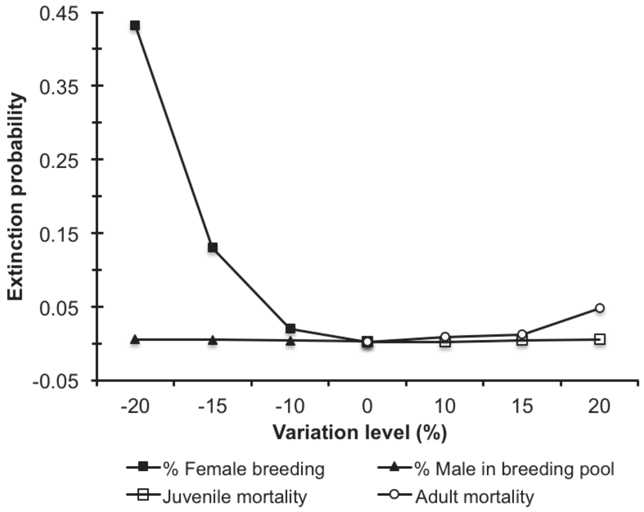

Figure 1. Extinction probability with variation of 10%, 15% and 20% in adult and juvenile mortality, and variation of -10%, -15%, -20% on percentage of females breeding and on percentage of males in breeding pool for the Mato Grosso Antbird (*Cercomacra melanaria*) population in the Pantanal of Poconé. The remaining variables are as in the basic scenario.

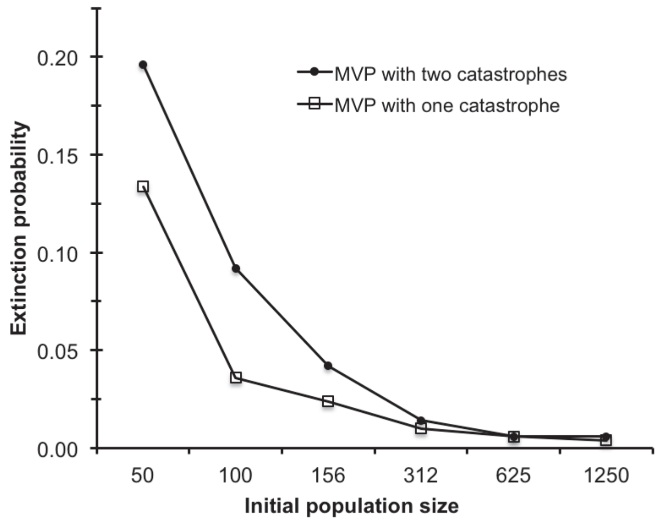

Figure 2. Relationship between initial population size and extinction probability for the Mato Grosso Antbird (*Cercomacra melanaria*) in the Pantanal of Poconé in scenarios with one (basic scenario) and two catastrophes.

Table 2. Results summaries of PVA of the Mato Grosso Antbird, *Cercomacra melanaria*, using program VORTEX.

Scenario	Extinction probability	Population growth rate (*r*)		Final population size ± SD
		Deterministic	Stochastic ± SD	
Basic	0.002	0.064	0.051 ± 0.198	3858.61 ± 1195.41
Mortality	0.002	0.163	0.152 ± 0.179	4787.05 ± 376.12
Fire	0.002	0.055	0.042 ± 0.198	3571.59 ± 1297.42

RESULTS

Population viability

The Mato Grosso Antbird population has a low risk of becoming quasi-extinct in the next 100 years (Extinction Probability = 0.002, basic scenario) (Table 2). Sensibility analysis showed that the percentage of reproductive females had the greatest impact on extinction probability, and mortality was less important (Fig. 1).

Minimum Viable Population (MVP)

Extinction probability (EP) was higher than 0.05 when the initial population size was 50 individuals (Fig. 2). With population sizes greater than 100 individuals, the population was viable (EP = 0.036). Thus, MVP of Mato Grosso Antbird with one catastrophe was approximately 100 individuals. With two catastrophes, MVP was around 160 individuals with low extinction probability (EP = 0.042) and positive stochastic population growth rate (Table 2, Fig. 2).

Sensibility analysis with MVP (160 individuals) as initial population size had a greater extinction probability than the basic scenario, and again the reproductive females have the greatest impact on extinction probability. However, in this scenario adult mortality rate was also important when reaching 10% greater mortality than in the basic setting (EP = 0.214). Additionally, the proportion of adult males that were reproductive as well as juvenile mortality was also important but their effects on extinction probability were weaker than reproductive females and adult mortality (EP = 0.052 and EP = 0.102, respectively) (Fig. 3).

DISCUSSION

Population viability

Demographic and environmental processes combined with the influence of catastrophes indicate that the Mato Grosso Antbird has low chance of becoming extinct under the prevailing conditions and a tendency towards positive population growth. Even when using pessimistic levels of proportions of reproductive adults and adult and

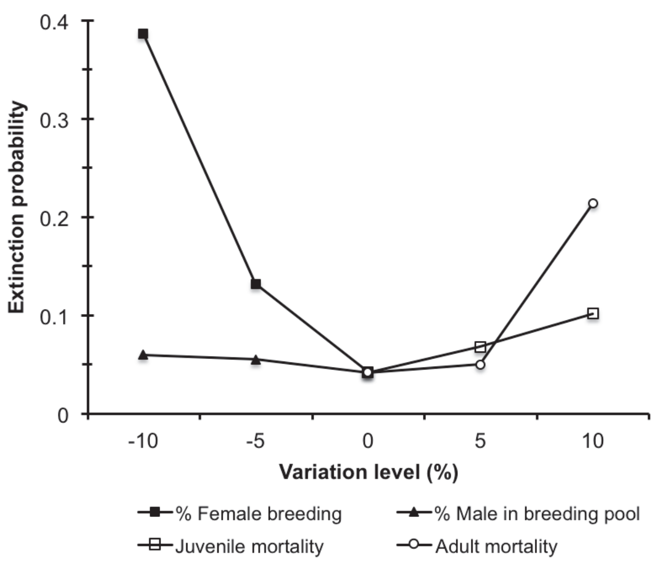

Figure 3. Extinction probability with variation of 5% and 10 % in adult and juvenile mortality, and variation of -10% and -5 % on percentage of females breeding and on percentage of males in breeding pool for the Mato Grosso Antbird (*Cercomacra melanaria*) population in the Pantanal of Poconé using the alternative scenario of MVP of 160 individuals and fire catastrophe. The remaining variables are as in the basic scenario.

juvenile mortality, extinction probability remains low. These results corroborate the classification of the Mato Grosso Antbird as "Least Concern" by IUCN criterion (BirdLife International 2016).

As indicated by the sensitivity analysis, the percentage of reproductive females is the most important parameter for extinction risk as in other bird studies (França & Marini 2010, Duca *et al*. 2009) and those of other vertebrates (Goldingay & Possingham 1995, Reed *et al*. 1998, Brito & Grelle 2006, Brito *et al.* 2008). Adult mortality was also indicated by the sensitivity analysis as the second most important parameter to population viability. Theses results suggest that management strategies (*e.g.*, nest protection - Duca *et al.* 2009) should be first directed at female reproduction to improve persistence in this population, and that future studies should prioritize estimates of fecundity and mortality, and their variances.

We highlight that our results are indicating a tendency of the Mato Grosso Antbird population in the study area, but the conclusions should be viewed with caution because there are some uncertainties in the input parameters of the model.

Minimum Viable Population (MVP)

The population size of Mato Grosso Antbird must remain above 50 individuals to be viable (> 95% chance to persist in the next 100 years). In a pessimist scenario with two catastrophes (fire and prolonged dry period), all populations of Mato Grosso Antbird higher than 150 individuals were viable. Other studies have similar results (*e.g.*, Soulé *et al.* 1988, Thomas 1990, Hamilton & Moller 1995, Leech *et al.* 2008) and estimates of MVP based on pessimist scenarios are more appropriated when the goal is to do a conservative analysis. Catastrophes, such as fire and long dry seasons, are known to impact the persistence probability of populations (Cahill & Walker 2000, Bolger *et al.* 2005, Dawson & Bortolotti 2006). Therefore, catastrophes raise the estimated MVP over that in the basic scenario to approximately 160 individuals.

Prolonged drought is important because the Mato Grosso Antbird begins reproduction with the onset of the rainy season (Pinho *et al.* 2006). Thus, due to its limited breeding season (Hau *et al.* 2008), a long dry season shortens the time interval over which reproduction may occur, thereby decreasing annual fecundity. If the frequency of dry years increases, population viability will subsequently decline (Bolger *et al*. 2005, Duca *et al.* 2009).

The influence of fire is more direct, as it reduces survival probability, causes habitat loss and degradation and may cause nest failure (Cahill & Walker 2000). Fire was associated with reduced reproductive success in *Falco sparverius* and *Aceros cassidix* (Cahill & Walker 2000, Dawson & Bortolotti 2006). This is likely to be a catastrophe that may increase its frequency in the Poconé area because of the common practice of burning fields every year (Harris *et al.* 2005).

When including the catastrophic events we can see the population sensitivity to the presence of such factors. Catastrophes affect population viability because they affect other parameters determining the continuity of the population persistence. The sensitivity analysis of scenarios with two catastrophes indicate that reproductive parameters are most relevant in the extinction process and should be prioritized in the definition of management strategies for Mato Grosso Antbird population. Studies carried out in the Cerrado Biome suggest that management strategies should be directed towards increasing reproduction rates rather than to manipulate other factors, such as habitat availability (Duca *et al.* 2009, França & Marini 2010). Also, adult survival is clearly important because the impact of stochastic variation in the size of the effective population can be eased by the presence of adults able to replace died breeders (Goldingay & Possingham 1995, Walters *et al.* 2002). Therefore, providing refuge or other means of escaping catastrophes are important management options (Duca *et al*. 2009).

The Mato Grosso Antbird population in the current demographic and environmental settings, including catastrophes, is not vulnerable to extinction. Therefore, the classification of the Mato Grosso Antbird as "Least

Concern" by IUCN criterion is suitable. The MVP that should be used in management decision-making is around 160 individuals. The demographic variable most influential in determining MVP is the proportion of adult females that reproduce.

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