Ethogram of the endangered Great-Billed Seed-Finch, Sporophila maximiliani (Cabanis, 1851) (Thraupidae: Passeriformes), based on captive-born individuals

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Abstract

Knowing the behavioral repertoire of a species is essential for in-depth research, especially for critically endangered species that depend on conservation efforts to avoid its extinction. In addition, knowledge of a species' behavior is essential for promoting its welfare under captive conditions. For example, endangered species that are to be reintroduced into the wild must be kept in captivity for rehabilitation and health assessment prior to release. The Great-billed Seed-finch, *Sporophila maximiliani* (Cabanis, 1851), is a critically endangered passerine, but we have a limited understanding of its behavior. Although rare in the wild, the species is commonly bred in captivity and these individuals are used to re-establish wild populations. Here, we provide the first description of the ethogram of captive-born individuals of *S. maximiliani*. We expect this to aid in the rehabilitation of individuals destined for reintroduction projects and the conservation of wild populations of the species. We described twenty-three behaviors, mainly distributed in the categories of maintenance, locomotion and alertness. We did not observe any abnormal behaviors, such as stereotyped behaviors, which is a positive signal for the welfare of these individuals. Also, the large number of alert behaviors observed is indicative of the reactivity of these individuals to their immediate environment, which is desirable for individuals to be released into the wild.

Introduction

The Great-billed Seed-Finch, *Sporophila maximiliani* (Cabanis, 1851), is a passerine of the family Thraupidae, known for its melodious singing (Machado *et al.* 2020). In nature, the species lives in pairs and exhibits territorial and aggressive behavior, especially during the breeding season (Ubaid, 2018). *Sporophila maximiliani* inhabits wet and flooded areas dominated by grasses, such as swamps and riparian forests (Ubaid, 2018). Historically, *S. maximiliani* had a large range, with two distinct populations reported: one typical of savanna formations with distribution in the southern and southeastern region of South America, including areas of the Brazilian Cerrado biome and areas of contact with the Atlantic Forest, and another population in the northern region of the Amazon (Jaramillo and Sharpe, 2020).

Despite the large historical range, there are few known wild populations and records of locations of the Great-billed Seed-Finch. Most of the records are based on museum collections, with the latest field records dating from 2014, in the state of Mato Grosso (Ubaid, 2018) and from 2020 in Minas Gerais, 80 years since the species was last reported in that state (Waita, 2020). This situation makes it difficult to find and observe the species in its natural habitat, and reflects the historical process of overhunting that these animals have been subjected to, highlighting the current extinction risk status of the species (Medolago et al. 2016). The rarity of the species in the wild is a result of the habitat loss and degradation, as well as pressure from illegal capture and animal trade (Sick, 1997; Destro et al. 2012).

S. maximiliani, which belongs to the suborder Passeri (Oscines), belongs to a group of birds with complex voice tract and great singing ability, commonly referred to as "songbirds" (Silva & Vielliard, 2011). In addition, oscines have a great capacity for learning and are able to expand their vocal repertoire throughout their lives (Marques 2009). These characteristics, the ability to sing and to learn,

make this species highly sought after by bird breeders, with singing tournaments held in different Brazilian regions, which include many species of the genus *Sporophila*, one of the most threatened by the wildlife trafficking (Destro et al., 2012). As a result, *Sporophila maximiliani* is the ninth species of greatest interest to bird breeders and the 27th species of the Brazilian wildlife most apprehended by the *Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais* (IBAMA) (Destro et al., 2012).

In light of these threats, the Great-billed Seed-Finch has been classified as critically endangered by the *Instituto Chico Mendes de Biodiversidade* (Portaria MMA nº 148, de 7 de junho de 2022) and is estimated to have fewer than 100 individuals in the wild (Ubaid et al. 2021), with a continuous downward trend (BirdLife International 2019). Contrary to its rarity in nature, *S. maximiliani* is actually abundant in captivity, with more than 175,000 individuals housed by legal breeders (Ubaid, 2018). As such, this species is on the verge of extinction and conservation efforts, including reintroduction programs of individuals, are needed to maintain viable populations in nature. However, the rarity of this species and the difficulty of making direct observations in the wild results in a lack of basic information about its biology and behavior, posing a major challenge to such conservation efforts (Medolago et al. 2016). The lack of data on the natural history of the species reduces the potential success of conservation efforts, as generalizing the known information for this species to its entire range or known populations may ignore variation or local adaptations to specific habitat conditions. In addition, the lack of information on the behavior of the species makes it difficult to compare the results of different research groups.

Another important question is how captive individuals of the species would behave in the wild, and whether it is possible to restore wild behaviors that are essential for the survival of reintroduced animals. Without behavioral data, we cannot fully understand their behavioral repertoire or compare it against wild individuals. Therefore, in this study, we present the ethogram for *Sporophila maximiliani* based on observations of captive-born individuals. To the best of our knowledge, we present the first report on the behavioral repertoire of the Great-billed Seed-Finch. Our data may aid future studies of the species that require the classification or quantification of its behaviors, allowing for standardization of ethological studies of the critically endangered *S. maximiliani*, as well as supporting the improvement of the welfare conditions of birds in captivity. In addition, the ethogram that we provide for captive-born *S. maximiliani* would be useful to allow comparisons with wild populations and to define behavioral modifications for individuals destined for reintroduction programs, rehabilitation, and monitoring, as well as helping to understand possible environmental effects on the species' behavior.

Material and Methods

We conducted our observations of *Sporophila maximiliani* individuals at the *Centro de Triagem e Reabilitação de Animais Silvestres* (CETAS-GO), located in the municipality of Goiânia, State of Goiás, Brazil. The CETAS-GO is a government center under the authority of the federal agency IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources), that receives animals from apprehensions, rescues, and voluntary surrenders. The specimens we observed were provided by CETAS, which houses a large number of *S. maximiliani* specimens from donations or apprehensions destined for

reintroduction into the wild, through the *Bicudos do Cerrado* project, carried out by the *Floresta Cheia* Institute.

This work is a by-product of a behavioral project conducted from March 5th to the 28th of 2022, aimed at evaluating the behavioral responses of *S. maximiliani* in response to the presence of an acoustic signal of another male individual or a predator. The experiment was carried out in a room (6.3m x 5m x 3m) with controlled air temperature (25ºC) during the period of maximum activity of the birds, between the hours of 7h00 and 10h00 and between 15h00 and 18h00, where the individuals remained in individual cages for five minutes before the start of the observation to acclimatize to the room conditions. We observed a total of 16.67 hours of recordings from 20 different individuals of *Sporophila maximiliani*, 10 males and 10 females.

We used a Sony® DCR-SX21 video camera to record any behavior displayed during the experiment and an AudioMoth® digital recorder to record any acoustic signal emitted. Each observation was conducted with one individual at a time, in individual cages, and each bird was used once. Thus, our observations did not include social, sexual, and parental behaviors that the species may exhibit. We analyzed all the records in the software BORIS 7.3, to describe the behaviors of *S. maximiliani*.

We based our descriptions on the ethograms of other passerine species (Porto and Piratelli 2005; Smith and Wassmer 2016). For behaviors with similar function and topology, we used the same name as the literature. Other behaviors with differences in one of these components were considered new behaviors. The use of animals in our experiments was approved by the Ethical Committee for the Use of Animals in Experiments of the Universidade Federal de Goiás (CEUA/UFG 077/21 approval).

Results

The individuals displayed a total of 23 behaviors, which were classified according to their function and topology into seven behavioral categories: maintenance, locomotion, ingestion/egestion, alert, vocalization, resting, and agonistic behavior. The description of all behaviors is shown in Table 1. The maintenance category had five behaviors, being the one with the largest number of behaviors, followed by the locomotion, ingestion/egestion and alert categories, both with four behaviors. The remaining categories, resting, vocalization, and agonistic behavior, presented three, two, and one behavior, respectively. Despite the lack of an ethogram of free range *S. maximiliani* to compare, no apparent abnormal (i.e., derived from chronic stress or a pathological condition) behaviors were observed.

Table 1
Ethogram of *Sporophila maximiliani.*

Category	Behavior	Description
Maintenance	- Autopreening	Handling each of the feather using the bill going over the entire length of the feathers
	- Bill cleaning	Scraping the bill repeatedly on the perch, especially after eating, to remove dirt. The head moves from side to side, allowing the scrape of both sides of the bill
	- Flapping of wings	Opening and flapping both wings simultaneously or alternately while standing on the perch, without displacement
	- Bill opening	Maintenance of the bill opened to thermoregulation, without any other movement of the body
	- Feather settling	Shake of the body while rapidly erecting the feathers to put in place the feathers. The feathers of the bird inflate while it shakes the body.
Locomotion	- Flight	Flapping wings on the air moving from one place to another, used to move short distances
	- Jump between perches	Jump between perches and/or among other types of support (cage, feeder or floor), without any movement of the wings
	- Walking on the perch	Walking laterally and moving around on the perch, without changing the direction of the body
	- Jumping laterally	Jumping sideways on the perch
Ingestion/egestion	- Eating	Handling and eating food on the feeder. The bird catches the seeds on the feeder using the bill and handles it to remove the peel. The inside of the seed is ingested
	- Foraging	Search for food on the ground or on perch, by moving down the head and making little movements of opening and closing the bill
	- Defecating	Lifting of tail feathers, slight tilt of the body and elimination of feces
	- Drinking	Dip the bill inside the water container and tilts its head up to shallow to ingest water
Alert	- Vigilance	Turn the head and/or body quickly in any direction for observation. The head is often not aligned with the body
	- Perch in the cage	Landing on the cage bars by its paws and quickly leaving
	- Jump on the perch changing orientation	Jumping on the perch by changing the body orientation. The movement does not promote

Category	Behavior	Description
		changing of location, just orientation.
	- Stretching the neck	Stretch the body and neck vertically, getting bigger
Vocalization	- Singing	Emission of long and complex vocalization, normally to reproduction or territorialism expression
	- Call	Emission of short calls or confrontation vocalization during stressing, conflicts, alert or other intra and inter specific situations
Resting	- Perching	Stand on the perch in the same position and with the head in the same direction of the body to rest
	- Sleeping	Stand quiet on the perch with the head nestled in one of the wings and the eyes closed
	- Sitting	Folding the paws so that they are hidden in the body and remain still to rest
Agonistic	Confrontation	Flighting toward the playback source as an aggressive attack to the possible competitor

The behaviors observed in a systematic way were separated into state and event behaviors for further analysis of frequency and duration of emission (Table 2). Two behaviors, sleeping and sitting, were observed anecdotally and thus were not included in duration analysis. Despite maintenance being the category with the most behaviors, locomotion and alert behaviors were the most frequent either for both males and females. Flight, jumping between perches, and jumping on the perch to change orientation were the three most emitted behaviors, while vigilance was the behavior in which they spent the most time. For males, there is also a large display of calls.

Table 2
Males and females percentage of emission of each behavior systematically observed.

Behavior	Type	Males percentage of duration or frequency	Females percentage of duration or frequency
Autopreening	State	0,59% (112.01s)	1,02% (143.89s)
Bill cleaning	Event	4,53% (75)	0,99% (25)
Flapping of wings	Event	2,36% (39)	0,32% (8)
Bill opening	Event	4,17% (69)	2,19% (55)
Feather settling	Event	1,15% (19)	2,46% (62)
Flight	Event	20,13% (333)	20,15% (507)
Jump between perches	Event	18,68% (309)	27,07% (681)
Walking on the perch	Event	0,54% (9)	0,20% (5)
Jumping laterally	Event	1,75% (29)	0,52% (13)
Eating	State	19,46% (3719.56s)	9,62% (1360.62s)
Foraging	State	1,44% (274.29s)	0,07% (9.94s)
Defecating	Event	0,60% (10)	0,16% (4)
Drinking	State	0,02% (2.99s)	0,00% (0s)
Vigilance	State	61,66% (11785.06s)	85,17% (12051.57s)
Perch in the cage	Event	4,59% (76)	4,89% (123)
Jump on the perch changing orientation	Event	17,29% (286)	27,74% (698)
Stretching the neck	Event	8,52% (141)	8,43% (212)
Singing	State	0,27% (52.06s)	0,00% (0s)
Call	Event	15,48% (256)	4,89% (123)
Perching	State	16,57% (3167.11s)	4,12% (583.18s)
Confrontation	Event	0,18% (3)	0,00% (0)

Discussion

The majority of the observed behaviors are topologically similar to the behaviors of other passerine species (Porto and Piratelli 2005; Smith and Wassmer 2016; Martinéz et al. 2022). However, by using a topological criterion to describe behaviors, we found a slightly larger number of behaviors compared to other ethograms that use a functional criterion to describe behaviors (e.g. Porto and Piratelli, 2005).

Therefore, we registered and described different behaviors that are used for the same function. For example, the behavior “moving from one place to another by propulsion with the feet” is usually classified as one behavior, but we separated it into three behaviors (“jumping between perches”, “walking on the perch”, “jumping laterally”) according to the direction and distance of the movement. We also did not record social behaviors (such as parental, sexual, and any behavior related to direct interaction between individuals), as stated in the methods section, with the exception of a type of agonistic behavior targeted toward indirect clues of another male's presence (male song).

The category with the largest number of behaviors was maintenance, which we found to be a common pattern in birds, as these behaviors are important for physiological self-regulation, feather care, and providing a state of comfort (Delius 1988). The behavior of “flapping wings” is rare in the passerine literature (Hubbard et al. 2015), but has been described in pigeons (Wittek et al. 2021; Delius et al. 1976). We classified this behavior in the maintenance category due to the context of the display, but the exact function of the behavior for *Sporophila maximiliani* is not yet fully understood, and it is possible that this behavior could instead have an alarm (Lehner 1987; Hubbard et al. 2015) or comfort function, or be displaced (Delius 1988). For example, grooming behavior may be briefly displayed among other behaviors aimed at resolving a stressful situation, which has been termed grooming displacement (Delius 1988) as a reference to a displaced activity (Tinbergen 1952). Understanding the functionality of behaviors requires in-depth observations that combine ecological context, environmental conditions, evolutionary relationships and, when available, physiological data from the species to fully understand the origin and function of the behavior. The combined analysis of evidence may be important even for common behaviors, since behaviors may be co-opted to new functionalities in response to the environmental changes or when faced with newer ecological contexts (Gould and Vrba 1982). Also, wing flapping may have the same function of as "wing stretching” and “scratching” behaviors, which are common in birds (Martinez et al. 2022; Henrique and Piratelli 2008; Herculano et al. 2013; Delius 1988; Delius et al. 1976) but were not displayed by *S. maximiliani*.

The second and third categories with the most described behaviors were locomotion and alertness, each with four behaviors. We did not include “flight” behavior because the observations were made with the animals in maintenance cages. Thus, they were unable to fly long distances and we classified all flight occurrences as “short distance flight” behavior. The alert category was the second with the most frequently displayed behaviors, showing that even in captivity, the individuals remained vigilant to their surroundings, once the alert behaviors were more frequently displayed in response to another male's call or an acoustic signal from a predator (G. Sales, pers. obs.).

In general, bird species have none or one behavior in the alert category (Porto and Piratelli, 2005; Henrique and Piratelli 2008; Smith and Wassmer 2016; Martinéz et. al 2022), even considering other behavioral studies with birds in captivity (Smith and Wassmer 2016; Herculano et al. 2013), but we observed four types of alert behaviors in *S. maximiliani*. The most common alert behavior in birds is “vigilance” (Herculano et al. 2013; Henrique and Piratelli 2008; Porto and Piratelli 2005; Hare 1998), a widespread antipredator behavior in prey species (Fernández-Juricic 2012), described as head

movements toward a focus of interest, but we also found descriptions of alert states displayed by neck stretching (Brown and Veltman 1986; Delius 1988). We chose to describe these alert states as two distinct behaviors because of the topological variation in the motor pattern. The other two behaviors in the alert category that we observed were not previously reported in the literature and appear to be a peculiarity of the Great-billed Seed-Finch.

We hypothesized that the environmental conditions experienced by the bird during life would influence the number of different alarm behaviors it could exhibit. For example, most studies of birds in captivity have been conducted in zoos (Herculano et al. 2013; Smith and Wassmer 2016), where individuals are exposed to higher visitation rates and a variety of natural and man-made sounds, which may reduce the responsiveness of individuals through a habituation process. Conversely, the individuals in our observations were kept in isolated cages, with limited human contact, which reduces the habituation to humans, an important predator for natural populations of this species. This may suggest that preventing habituation to humans and to new stimulus during the temporary housing of individuals may be an important condition to increase the success of reintroduction projects.

We did not observe any abnormal behavior, which is present in many behavioral studies with birds in captivity (Mellor et al. 2017; van Hoek and ten Cate, 1998). This could be a consequence of studies conducted with animals taken from the wild (van Hoek and ten Cate 1998, but see a review in Mellor et al. 2017) compared to studies conducted with captive-born individuals, as in our study. In captive-born individuals, familiarity with captive conditions would reduce the emission of abnormal behaviors. Another reason for the absence of these behaviors may be the maintenance conditions with environmental enrichment, which reduces the display of stereotyped behaviors (Fairhurst et al. 2011). Smith and Wassmer (2016) described the “cage stereotypy” behavior, which is similar to our “perch on the cage” behavior. However, while Smith and Wassmer (2016) considered it to be an artifactual behavior induced by the conditions of captivity, we did not consider it to be a consequence of the birds' confinement due to the context of the behavioral emission. The passerines perched on the cage grids to approach the source of the male playback calls, as if they were trying to find the intruding male. Therefore, we interpreted it as an alert behavior. Furthermore, the movement was not displayed several times in a row, a characteristic of stereotyped behaviors (Mason 1991). Finally, the absence of abnormal behaviors should not be interpreted as an absence of stress, since normal behaviors can also indicate a state of stress, depending on the context and frequency of display, such as the increasing display of maintenance behaviors (Neto et al. 2021; Dawkins et al. 1991; Santos et al., unpublished data).

Although we did not provide social interactions with other individuals, we were able to register one behavior in the agonistic category, “confrontation”. As a territorial species, both males and females are expected to exhibit aggressive behaviors to defend their territory when exposed to the presence or cues of another male (Lenis and Guillermo-Ferreira 2019; Fokidis et al. 2010), but in our observations, “confrontation” was exclusively exhibited by males. The emission of “confrontation” occurred in response to the playback of another *S. maximiliani* male song. Despite this, we described only one aggressive behavior, probably because of the same explanation for the alert category, but with an

opposite trend: free-range individuals should display a more diverse aggressive repertoire than captive-born individuals (Martínez et al. 2022; Smith and Wassmer et al. 2016). Furthermore, we chose to classify “calling” and “singing” behaviors in the vocalization category, as these behaviors may have different functions depending on the ecological context, and to follow the descriptive standard in the passerine behavior literature (Porto and Piratelli 2005; Herculano et al. 2013; Smith and Wassmer et al. 2016; Martinéz et al. 2022). However, these behaviors are also social as they are used to communicate with other individuals. The song of the Great-billed Seed-Finch is used either to signal territorial defense and the attraction of females by males (Langmore 1998; Catchpole and Slater 2008; Ubai et al. 2018), while the calls can signal food and predator presence, or other different environmental conditions to cospecific individuals of both sexes (Langmore 1998).

Conclusion

We described the behavioral repertoire of the Great-billed Seed-finch, *Sporophila maximiliani*, which showed a wide range of behaviors in the categories of maintenance, locomotion, and alertness, some of which were exclusive to the species. This reinforces the importance of basic behavioral studies to unravel the particularities of each species. Furthermore, the large repertoire of behaviors in the alert category brings a great perspective to the release of the captive individuals into the wild, supporting the possibility of success of reintroduction programs of the species. We hope that this ethogram may help further studies with *S. maximiliani*, as well as the other species of the genus *Sporophila*, which is vast and composed of widely managed species.

Declarations

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Author Contribution

G.S.S, F.N, A.A.M.X, and L.A.M.L.B contributed to the conceptualization. G.S.S and L.L.L made the data curation, investigation and formal analysis. G.S.S performed the writing - original draft. F.N made de supervision. All authors contributed to the designing of the methodology and writing - review and editing.

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study complies current national laws and was approved by the Ethical Committee for the Use of Animals in Experiments of the Universidade Federal de Goiás (CEUA/UFG 077/21 approval)

Data Availability

The data supporting the research are the raw data files available at https://doi.org/10.5281/zenodo.10428308

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