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CONSERVATION OF THE ORINOCO GOOSE (*NEOCHEN JUBATA*) IN THE MIDDLE ARAGUAIA RIVER, TOCANTINS, BRAZIL

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Abstract · The Orinoco goose (*Neochen jubata*) is a grazing herbivore of open habitats that was once widely distributed in tropical South America. Centuries of overhunting and loss of important habitats have reduced it to widely scattered remnant populations and it is categorized as Near Threatened globally. Within the *cerrado* biome, the Middle Araguaia River houses the largest remnant population, where it uses natural and agrosystems, especially rice. In August 2017, a study was started to assess the situation of the Orinoco Goose in the regions of Araguaia National Park, Cantão State Park, and adjacent rice fields. We conducted counts from an aerial census (a 700 km transect), monthly boat censuses (40 km), and land censuses, including rice plantations. The aircraft census counted 367 individuals in August 2017, while monthly monitoring of a stretch of the lower Javaés River over more than two years showed a seasonal population variation associated to the flood regime, with the species virtually disappearing during the flood period between January and April, when river beaches are submerged. During this period, large flocks of about 1,000 Orinoco Geese were discovered concentrated in small stretches of rice plantation agrosystems in the region. This behavioral pattern of concentrating in a restricted geographic area makes the species susceptible to poisoning and epizootic diseases. The findings suggest the need to re-categorize the Orinoco Goose population of the Middle Araguaia River as "Endangered" for the state of Tocantins due to the decline observed in the last 10 years, the maximum estimated population size, and the significant seasonal concentrations in a restricted area. At the same time, it is necessary to develop an action plan for its conservation in the surroundings of Ilha do Bananal and throughout Brazil, where its threat status must be reviewed.

Resumo · Conservação do pato-corredor (*Neochen jubata*) no médio rio Araguaia, Tocantins, Brasil
O pato-corredor ou marrecão (*Neochen jubata*) é um herbívoro especializado em pastar em formações abertas ribeirinhas, assim como algas filamentosas macroscópicas, com distribuição geográfica histórica em boa parte da América do Sul tropical. Séculos de caça excessiva e perda de habitats cruciais pela ação antrópica resultaram nas atuais populações esparsas da espécie, sendo categorizado como Near Threatened internacionalmente. A região do médio rio Araguaia, entre os estados do Tocantins, Pará e Mato Grosso, abriga a principal população do pato-corredor no bioma Cerrado, onde é encontrado tanto nas florestas e cerrados inundáveis, como em plantios de arroz irrigado. A partir de agosto de 2017, um estudo dessa população no parque nacional do Araguaia, parque estadual do Cantão e arrozais irrigados próximos foi iniciado. Foram realizados censo aéreo (transecto de 700km), censos mensais por barco em 40km do baixo rio Javaés e censo por terra nos plantios de arroz irrigado. O censo aéreo resultou na contagem de 367 patos-corredores em agosto de 2017, enquanto o censo mensal por barco evidenciou uma variação populacional associada com o regime de cheias, com a espécie praticamente desaparecendo entre janeiro e abril, quando o pico estacional das cheias cobre as praias. No mesmo período e não muito distante, grandes grupos de patos-corredores somaram cerca de 1.000 indivíduos e foram descobertos na região do médio rio Javaés, concentrados em uma pequena porção dos plantios de arroz irrigado. Esse comportamento altamente gregário e geograficamente muito restrito torna a espécie suscetível a eventuais envenenamentos e surtos de epizootias. Tais resultados sugerem que a população do pato-corredor do médio rio Araguaia necessita ter uma revisão de seu status de conservação, colocando-a como "Ameaçada" no estado do Tocantins. Apoiam essa revisão a queda populacional observada nos últimos 10 anos, o tamanho máximo estimado e as significativas concentrações estacionais de indivíduos em área muito restrita. Ao mesmo tempo, é necessário estabelecer um plano de ação para sua conservação no entorno da ilha do Bananal, bem como avaliar a situação no restante do Brasil.

Key words: Anatidae · Migration · Population census · Red lists · Seasonal concentration · Threats

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INTRODUCTION

Aquatic environments are areas of high productivity that are vitally important to maintaining high biodiversity (Getzner 2002), while also providing various ecosystem services of great social, economic, and cultural importance (Green & Elmberg 2014). However, they are among the most threatened ecosystems on the planet (Gopal et al. 2000, Maltby 2009) and are considered a priority for conservation measures (Gopal et al. 2000, Castello & Macedo 2016). It is estimated that more than 50% of global freshwater environments have been converted to different uses (Millenium Ecosystem Assessment 2005, Cunha et al. 2015), with agriculture being the main activity responsible for their decline (Czech & Parsons 2002; Junk et al. 2013).

In South America, the continent recognized as the most humid on the planet (Wittmann et al. 2015), aquatic environments cover approximately 20% of its surface (Junk et al. 2013). Most aquatic environments in South America are tied to flood pulses and oscillate between terrestrial and aquatic habitat depending on the timing, intensity and frequency of precipitation throughout the year (Junk et al. 2013). In central Brazil, the alluvial plain of the Middle Araguaia River maintains one of the most important complexes of aquatic environments in the country, presenting an extensive system of lakes fed by a flooding regime that favors connectivity and high productivity (Aquino et al. 2008). However, the region, like the *cerrado* biome more broadly, is also experiencing a marked process of environmental degradation promoted mainly by the expansion of the agricultural frontier (Morais et al. 2005, Junior et al. 2020, Sano et al. 2020).

The transformation of aquatic environments by agricultural monocultures puts ecosystem services at risk while also severely impacting biodiversity and the species that depend on these habitats (Verhoeven & Setter 2010). The use of agricultural fertilizers and pesticides compromises the entire biological chain, pollutes soil and water, and affects human health (Wittmann et al. 2015). Brazil stands out as a world leader in both per capita and per-hectare use of these chemicals (IBGE 2012, Dowler 2020).

The main grain grown in flooded areas worldwide and one of the main agricultural crops responsible for converting natural aquatic environments is rice (*Oryza sativa*) (Maclean et al. 2002). However, due to characteristics of the management of rice, areas cultivated under irrigation have a rich flora (Amarulla et al. 2017) and associated fauna, containing a high wealth of invertebrates (Zhang et al. 2019), fish (Katano et al. 2003), amphibians (Machado & Maltchic 2010) and birds (Acosta et al. 2010).

Aquatic birds are especially attracted to rice-growing agrosystems and have been registered in large numbers (Tubelis et al. 2020). The crop also attracts a multitude of species besides the waterfowl, motivated by the variety and abundance of food, but especially rice grains (Stafford et al. 2010, Justo 2019). Some of these birds are harmful economically, while others are beneficial to crop productivity, reducing insect pests, breaking down straw, and importing nutrients (Elphick 2010; Green & Elmberg 2014). In areas where rice is grown on the floodplain of the Middle Araguaia River, a wide variety of birds have been recorded, many of them endemic and/or endangered (Pinheiro & Dornas 2009). The Orinoco Goose (*Neochen jubata*) is one species that uses natural wetlands, as well as irrigated rice plantations, in the region of the Middle Araguaia River (Pinheiro & Dornas 2009, Tubelis et al. 2020). It inhabits riverine sandbanks, the banks of flooded lagoons, and savannas (Sick 1997, Carboneras 1992). It nests in tree cavities, possibly in ravines, and in the soil between roots of fallen trees (Kriese 2004). It feeds on grasses that grow in these environments, as well as algae and invertebrates (Carboneras 1992, Kriese 2004). Endemic to the Neotropical region, the Orinoco Goose's distribution includes Guyana, Venezuela, Colombia, Ecuador, Peru, Bolivia, Brazil, Paraguay, and northern Argentina (del Hoyo 1992, Hilty 2003, Kriese 2004, Luna et al. 2008, Pinheiro & Dornas 2009, Endo et al. 2014, Birdlife International 2016, Davenport et al. 2020). Originally, it occurred in nearly all of Brazil, being rare or absent on the coast, but common on sandy beaches along medium and large rivers, particularly those with well-developed riparian forest (Bressan et al. 2009).

Currently, four remaining large populations of the Orinoco Goose are recognized, occurring in remote areas of environments partially or totally protected by conservation units. These are the Middle Juruá River in the Amazon, the Middle Araguaia River, and other *cerrado* sites in central Brazil (Tubelis et al. 2020), the Department of Beni in Bolivia and the Llanos in the south of Venezuela and Colombia (Endo et al. 2014), as well as a fifth population of undetermined size in the Branco River, Roraima, northern Brazil (Naka et al. 2007). Information on population numbers (Endo et al. 2014), and migratory movements (Davenport et al. 2012) are still incipient, as well as long-term monitoring of different populations. In most cases, the species is identified through occasional sightings (Laranjeiras 2010, Lima 2011, Endo et al 2014, Tubelis et al. 2020) and/or sporadic records resulting from ornithological inventories (Silveira & D'Horta 2002).

The Orinoco Goose is considered globally Near Threatened with extinction due to its recent population reductions, attributed to environmental changes promoted by agriculture and hunting pressure (Birdlife International, 2016), although large hydroelectric dams may also play an important role in population declines, as indicated for the Paraná River basin in the state of São Paulo (Develey & De Luca 2009). Global estimates point to a population of between 10,000 and 25,000 mature individuals (Birdlife 2016). In Brazil, its total population has not yet been estimated, but there is evidence of a decline, as it appears on the list of threatened species in the state of São Paulo (São Paulo 2014). Currently, in the Paraná River basin only a residual population is known, located at the foot of the Andes of Argentina (Luna et al. 2008).

The present study aimed to analyze the current situation of the Orinoco Goose and assess the appropriate level of threat to the population of the Middle Araguaia floodplain, one of the most important populations in central Brazil (Pinheiro & Dornas 2009, Tubelis et al. 2020). To analyze the current situation, we undertook air, boat and terrestrial censuses from August 2017 through to February 2020, and compared geographic distribution, seasonal occurrence and abundance that we observed with existing prior data. To assess threats, we focused particularly on the possible consequences of the population's seasonal concentration in irrigated rice fields, while also highlighting local and statewide information on policies currently in place, poten-

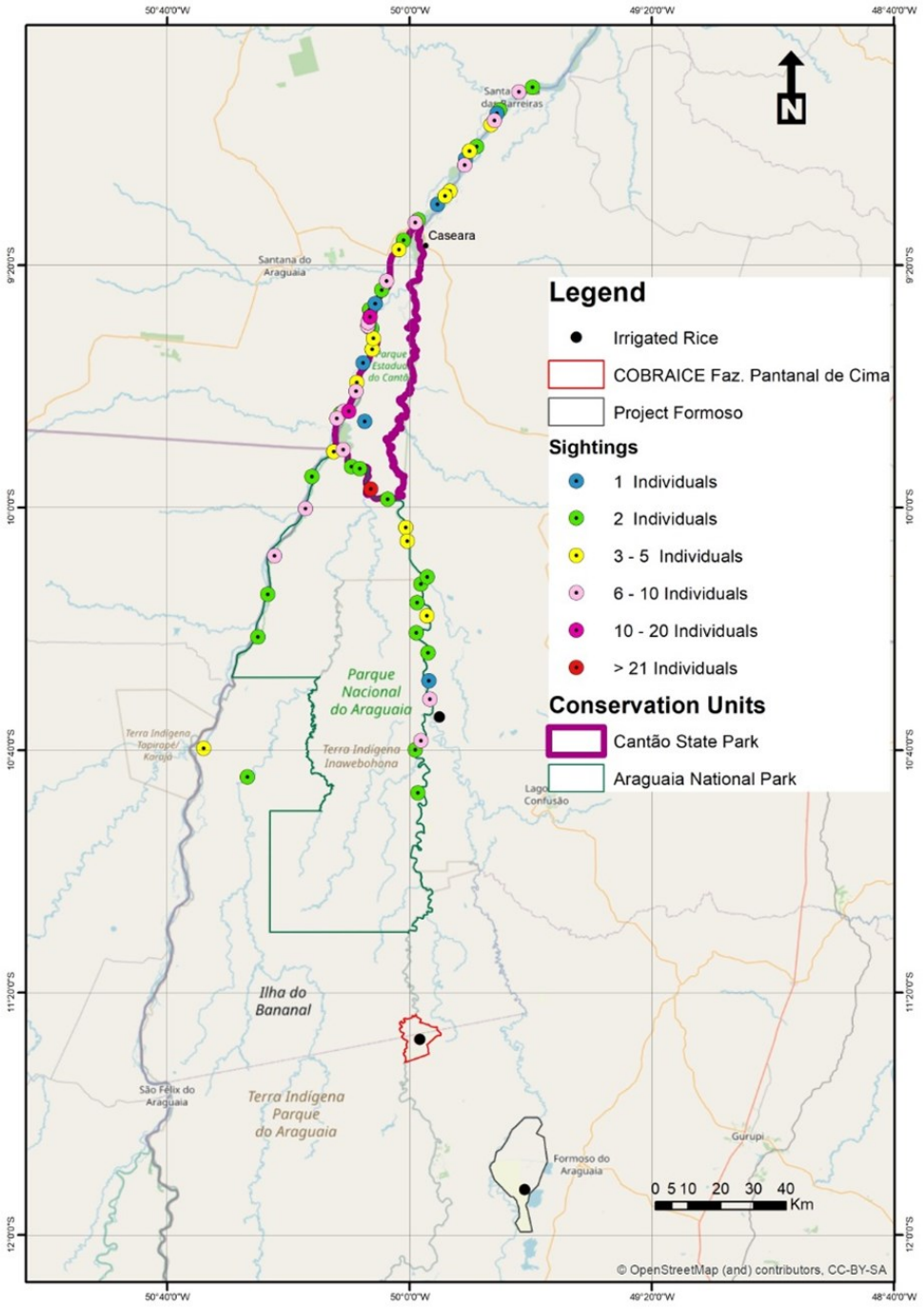

Figure 1. Spatial distribution of flocks of Orinoco Geese (*Neochen jubata*) sighted in the aerial census of August 2017 in the region of the Middle Araguaia River.

tial threats and policy needs, while reviewing the species' current conservation status throughout its range.

METHODS

Study area. This study was carried out in the floodplain of the Middle Araguaia River, at the convergence of the states of Tocantins, Mato Grosso and Pará. Sampling took place in the northern portion of Bananal Island – a fluvial island formed by the Araguaia and Javaés rivers – up to the municipality of Araguacema, a straight-line distance of around 250 km downstream from the meeting of the rivers. The information presented here was obtained within the natural ecosystems of the two main Integral Protection Conservation Units in the region–Araguaia National Park and Cantão State Park–within the limits of the Ilha do Bananal/Cantão Environmental Protection Area, as well as in local rice fields of Barreira da Cruz (10°33´S 49°56´W), municipality of Lagoa da Confusão, in the central-western region of Tocantins (Figure 1).

According to the Thornthwaite-Mather system, the climate in the region is B2rA'a 'type – humid with little or no water deficiency and experiencing two well-defined seasons: a dry season between May and October, and a rainy season between November and April. The average annual temperature is 28°C, with average annual rainfall around 1,700 mm, and a range of 1,000–1,800 mm (SEPLAN 2008). The vegetation of the region is in transition between the *cerrado* and the Amazon Forest, containing several formations, most notably alluvial semi-deciduous forests, *ipucas* (natural forest fragments) and *varjões* (seasonally flooded areas of typical *cerrado* and *campo de murundus*). The region is subject to

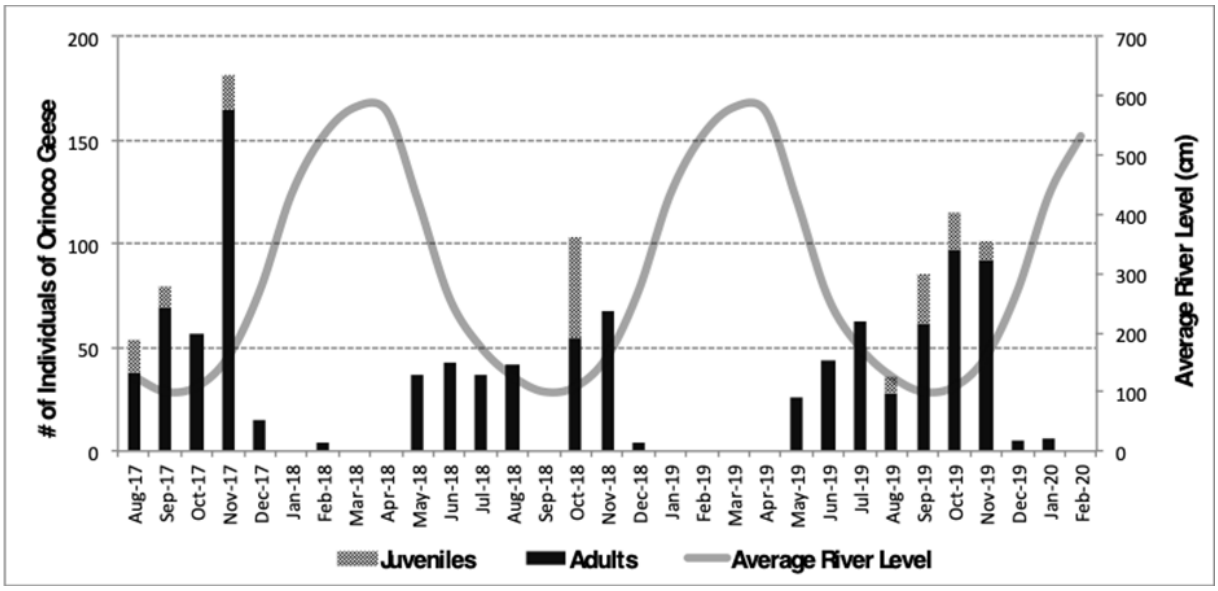

Figure 2. Monthly distribution of the Orinoco Goose (*Neochen jubata*) population sampled by boat along 40 km of the Javaés River, distinguishing adult and juvenile birds as described in text. Fluviometric data of the Araguaia River represented as average values of the historical series from the stations at Barreira do Campo and São Felix do Araguaia. No censuses were conducted in January, March, April and September 2018, or February to April 2019.

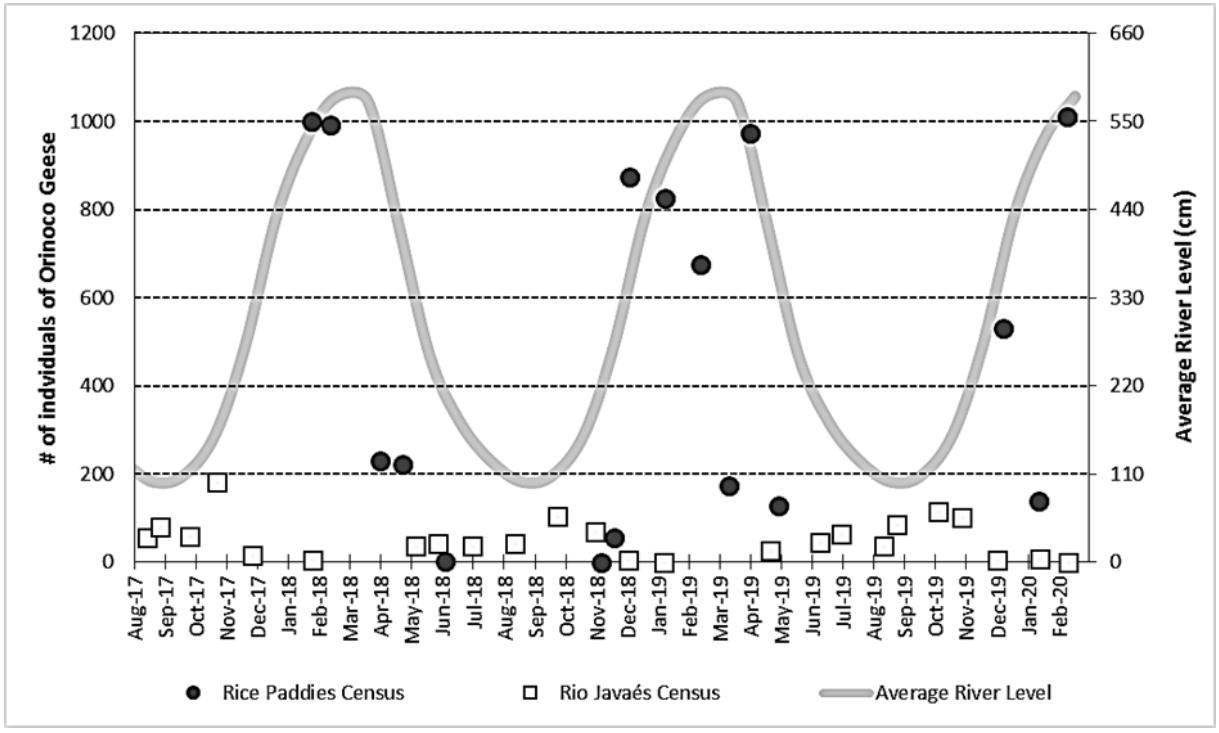

Figure 3. Seasonal distribution of the Orinoco Goose (*Neochen jubata*) population sampled by boat along 40 km of the Javaés river (white squares) and by land in the rice-growing agrosystems in the municipality of Lagoa da Confusão (black dots). The X axis shows actual dates of census counts. Fluviometric data of the Araguaia River represented as average values of the historical series from the stations at Barreira do Campo and São Felix do Araguaia.

severe seasonal flooding that modifies the landscape and the distribution of resources throughout the year. According to the historical fluviometric series provided by the Brazilian National Water Agency (ANA 2017), the annual variation in the level of the Araguaia River averages 4.45 ± 0.88 m in São Félix do Araguaia (N = 42 years, extremes of 3.26 and 7.69 m) and 5.29 ± 0.98 m in Barreira do Campo (N = 29 years, extremes from 3.91 to 8.93 m), based on fluviometric stations located upstream and downstream of the study, respectively. The peak of floods occurs between March and April, and the minimum water level occurs between September and October. These data were used to compose the seasonal fluctuation pattern of the Javaés river level in the present study, based on the average values of the two fluviometric stations mentioned above (Figures 2 and 3).

Data collection. Orinoco Goose censuses in the Middle Araguaia River were performed from August 2017 through to February 2020 using complementary techniques: one census by plane, multiple censuses by boat, and terrestrial censuses by car. On several occasions, choices in location terrestrial censuses were informed from satellite tracking of individual birds via ARGOS and GSM transmitters, data that will be reported elsewhere when tracking data finishes accruing for all individuals.

The aircraft census was carried out on 22 August 2017,

Figure 4. Concentrations of Orinoco Geese observed in Lagoa de Confusão rice fields, 2018. Photo by Renato Pinheiro.

with a 700 km transect covered primarily along the Araguaia and Javaés rivers (Figure 1). A high-wing Cessna 210 aircraft was used in low altitude flight (between 60 and 100 m in height). Two researchers, each positioned on one side of the aircraft, were responsible for counting and georeferencing Orinoco Goose individuals. Despite the aircraft's speed (~ 180 km/h), the aerial census makes it efficient to enumerate flocks and individual birds present on exposed beaches, providing a population panorama of the Orinoco Goose on a wide geographical scale. As some individuals remained hidden in the riverside vegetation and were therefore difficult to detect from the aircraft, a correction index of 1.35 was used, calculated from the proportion between the values recorded in the most comparable boat census and in the airplane census. Using these two methods applied a week apart, we compared the same stretches of river to generate the correction factor.

Boat censuses were carried out from early morning to mid-afternoon on one day per month, from August 2017 to February 2020, except when flooding or logistics precluded the work (Figure 2). Exceptions include January, March and April 2018, and January–March 2019 and February 2020, when the beaches were submerged, plus September 2018 for operational reasons. The boat traveled at an approximate speed of 20 km/h along a 40 km course of the Javaés River, between Araguaia National Park and Cantão State Park. The individuals and groups observed were quantified and georeferenced. Whenever possible, juveniles were differentiated from adults; we differentiated ages mainly by size and the duller/mixed plumage of juveniles.

Terrestrial population censuses were carried out by car in early morning hours to mid-afternoon hours one day per month in the rainy season, with some exceptions (Figure 3). For example, we made visits twice in both February and December 2018 (each census is included in Figure 3). These included visits to rice fields where satellite-tracked birds were known to be present at Barreira da Cruz (10°33'44.19"S 49°56'5.05"W), Emperor (10°29'33.81"S 49°55'51.22"W), and Canaã farms (10°33'50.11"S 49°54'38.68"W). The counts were performed from the roads between rice fields using a 4x4 vehicle at low speed (~ 20 km/h), with stops whenever necessary. The observations were made between 10:00 h and 16:00 h, covering an area of approximately 1,000 ha. We used Nikon 10x42 binoculars and photographic cameras for documentation of the large flocks and subsequent recounts. As in the other censuses, the locations of individuals were georeferenced with the aid of a handheld GPS unit.

On 23-24 February 2018, immediately following a terrestrial census in the Barreira da Cruz rice paddies, two other extensive rice plantations in the Javaés River basin were also ground-searched for the presence of the Orinoco Goose: the COBRAPE project (Pantanal de Cima farm), with 20,444 ha of irrigated rice on the banks of the Javaés River, and the Formoso Project in the Middle stretch of the same river, with about 30,000 ha of irrigated rice. Both are in the municipality of Formoso do Araguaia and located about 100 km (COBRAPE) and 145 km South (Formosa) from the Barreira da Cruz rice paddies (Figure 1).

RESULTS AND DISCUSSION

Population census on the Araguaia and Javaés rivers. During the aerial census, 63 groups of *N. jubata* were detected, totaling 272 individuals. Only three flocks (4.8%) had more than 10 geese, with just over half of the sightings consisting of two (38.1%) or just one individual (12.7%) (Figure 1). The distribution and size of the flocks were compatible with expectations for the reproductive period, when the river is low,

beaches are exposed, and most geese are in pairs.

Adjusting the census value using the correction index obtained from comparing boat and airplane censuses of the same stretch and period, the population of the Orinoco Goose over the 700 km aerial route was estimated at 367 birds. This is a relatively low value considering the large scale of the sampling and the fact that the route included the best-preserved stretches of rivers that delimit the conservation units in the region.

The raw value of the aerial census produced an index of 0.39 Orinoco Geese/km along the transect, while the corrected value produced an index of 0.52 Orinoco Geese/km. These figures are lower than those found in aerial censuses in the Meta River basin in Colombia (Ruiz-Guerra et al. 2014), but similar to numbers of birds found on Juruá River beaches (Campos-Silva et al. 2021). In Colombia, using data from three annual censuses along a 350 km transect of river, the indices of abundance were 23.11 (March), 10.62 (July), and 0.64 Orinoco Geese/km (November) (Ruiz-Guerra et al., unpubl.). Note that, being in the Northern Hemisphere, the dry and rainy seasons in Colombia occur in the opposite periods to the Araguaia River basin, with March corresponding to the end of the dry season, July the middle of the rainy season, and November the end of the rainy season (Ruiz -Guerra et al. 2014). On Juruá River beaches (northern Brazil, with seasons similar to the Araguaia basin), during foot-based censuses of approximately 155 beaches, representing a ~1,600 km stretch of the river, 582 Orinoco Geese were censused and estimated at 0.36 individuals/km of river not applying a correction factor (Campos-Silva et al. 2021).

The results of the aerial census also showed a geographically heterogeneous distribution of Orinoco Geese on the Araguaia and Javaés rivers in late August. On the Araguaia River, within the northern section of Araguaia National Park, we recorded far fewer individuals than along the banks downstream of either Cantão State Park or the Ilha do Bananal/Cantão APA. On the Javaés River, on the section above the UFT Canguçu Research Station, we recorded fewer individuals than in the section downstream. In the inlets and lakes of the interior of Cantão State Park, we registered a density of Orinoco Geese much lower than on the banks of the Araguaia River in the same conservation unit (Figure 1).

Seasonal dynamics of the population on the Javaés River. In general terms, the population dynamics of the Orinoco Goose in the Javaés River were inversely proportional to the fluviometric level of the Araguaia River. More records of the species were made in the river channel during the dry season, a fact undoubtedly related to the availability of sandy beaches with grasses and other seasonal herbaceous plants, the main food of the herbivorous Orinoco Goose. When waters rise, the beaches they feed on became scarce or disappeared entirely, forcing the geese to look for resources in other habitats. These annual trends generally repeated and the population remained relatively stable, although there were some minor differences among years. As in observations made by aerial census, the Orinoco Geese were observed to distribute predominantly as individuals or in small groups (13.8% solitary individuals and 32.4% in pairs), with the highest concentrations being detected in October and November, thanks to the presence of juveniles and the increasingly gregarious behavior of adults.

Seasonal concentrations observed in rice plantations. Terrestrial censuses results uncovered very high concentrations of Orinoco Geese in rice fields of Barreira da Cruz during flooded periods of the Araguaia and Javaés rivers (Figures 3). On 4 February and 23 February 2018, approximately 1,000 individuals of Orinoco Geese were counted (Figures 4 and 5). The following months showed a steady reduction in their numbers, until they were almost completely lacking by June 2018. This same area was overflown in August 2017 and no Orinoco Geese were observed, despite presence of plantations of irrigated soybeans at the time —irrigated soybeans are planted annually between April/May and September, according to the schedule determined by the state of Tocantins Agriculture Authority (ADAPEC 2019). In the next rice planting cycle, no Orinoco Geese were detected (18 November 2018). However, numbers increased dramatically between 1 December (56 Orinoco Geese) and 16 December 2018, when 873 Orinoco Geese were counted. In April 2019, there was a peak of 973 individuals observed, followed by a substantial reduction in May 2019 (128) as the Araguaia River dropped. Again, in December 2019, high numbers of Orinoco Geese (531) were found in the rice paddies, with a peak of 1010 counted in February 2020, though only 138 were found in January 2020 (Figure 3). This sudden drop in Orinoco Geese numbers during the mid-rainy season appears to be associated with a delay of the annual Javaés River flood in 2020, when most river beaches were not submerged until February. A better assessment of the Orinoco Goose population dynamics should correlate the species' numbers with the fluviometric regime of the same year, instead of with historical averages. Such an approach could also measure the critical river levels, triggering population displacements and congregations. It is clear overall, however, that because these terrestrial census counts of Orinoco Geese in rice fields resulted in observations of higher numbers of birds than those recorded previously during a large-scale aerial census (including these areas and along much of the Araguaia and the Javaés rivers of the area), there must be an immigration of Orinoco Geese from an even greater geographical area than our aerial census encompassed. This pattern has previously been unknown and deserves further investigation and monitoring to learn the origin of these immigrants.

Geographical distribution. Geographical distribution is a consideration in threat assessment, since animals with small distributions could be more vulnerable to single catastrophic events. Assessing the distribution of all points where Araguaia Orinoco Geese were observed in rice plantations during the monitoring study, they dispersed over a maximum area of 5,000 ha of rice paddies, a territory that is still very small for a concentration of so many individuals. This area is located in a group of rice fields with similar agricultural management, covering about 55,000 continuous hectares in the municipality of Lagoa da Confusão. In February 2018, in the days immediately following the surprising census that uncovered a great concentration in the Lagoa da Confusão rice paddies, two other extensive rice plantations in the Javaés River basin were also searched for the presence of *Neochen*: the Formoso Project, in the middle stretch of the river of the same name, with about 30,000 ha of irrigated rice, and the COBRAPE project (Pantanal de Cima farm), with 20,444 ha of irrigated rice on the banks of the Javaés River, both in

Table 1. Conservation status of the Orinoco Goose (*Neochen jubata*) in different regions throughout its geographic distribution.

Region	List	Threat Category	Reference
Global	IUCN	Near Threatened	BirdLife International 2016
National	Argentina	Critically Endangered	MAyDSyAA 2017
National	Bolívia	Least Concern	MMAyA 2009
National	Brazil	Least Concern	BRASIL 2014
National	Colombia	Vulnerable	Renjifo et al. 2016
National	Ecuador	Vulnerable	Granizo et al. 2002
National	Peru	Vulnerable	SERFOR 2018
National	Venezuela	Near Threatened	Rodríguez & Rojas-Suárez 2008
State	São Paulo	Critically Endangered	Bressan et al. 2009

the municipality of Formoso do Araguaia, and located about 100 km away from rice fields in Lagoa da Confusão. No individuals of the species were detected in these other sites, nor did local rice planters report its presence among the other waterfowls in the paddy fields, although it is a bird known and indicated by them as occurring along the Javaés River. Other rice fields on the Araguaia plain should be monitored regularly to assess if there are additional as-yet unknown key concentrations during the flood seasons, and if these remain stable over time.

Potential Threats

***Poisoning*.** Many organisms are attracted to rice culture, and some are considered harmful and requiring chemical control. Parsons et al. (2010) identified 274 chemical components (e.g., pesticides, herbicides) used in rice crops around the world, which can lead to direct and indirect poisoning from contamination of land and water and food of birds (grains, insects) or other organisms in the food chain. Some birds are considered pests themselves and there is evidence of the use of pesticides (organochlorines and organophosphates) for the direct control of birds in rice fields in Argentina (Bernardos & Saccagnini 2008), Venezuela, and Bolivia, making rice one of the riskiest crops for birds (Parsons et al. 2010). Migratory birds such as the Orinoco Goose are especially susceptible to neurotoxic insecticides, which can compromise their ability to orient and thus to migrate successfully, increasing the risk of mortality for some species (Eng et al. 2017).

Orinoco Geese have been observed sharing rice fields with other bird species that have long been considered by farmers to cause economic damage in rice fields, such as the White-faced Whistling-Duck (*Dendrocygna viduata)* and the Black-bellied Whistling-Duck (*D. autumnalis)* (Justo 2019*)*. In the event of any poisoning (or other direct control method) of waterbirds by rice farmers, whether due to the actual or perceived/potential economic loss, the Orinoco Goose could be affected, including Middle Araguaia birds and populations that immigrated to this region. In Brazil, reports indicate illegal bird poisoning in rice crops in São Paulo, Minas Gerais, Goiás, Santa Catarina and Rio Grande do Sul, but data available in the literature are rare (Silviconsult Engenharia 2003).

Epizootics and Parasites. A second potential threat in the Middle Araguaia is a disease outbreak, such as an epizootic event or parasitic introduction spread by the domestic fowl or other wild birds. Parasites of the genera *Ehrlichia, Anaplasma, Babesia, Plasmodium* and *Haemoproteus* have been identified in the population of the Orinoco Goose in the *cerrado* biome, including individuals co-infected by two or more parasites (Werther et al. 2017). Given the highly concentrated populations of Orinoco Geese and other waterbirds observed in this study, and their use of recently converted agricultural systems each wet season, individuals may be more frequently interacting with domestic animals and other wild birds, and are now concentrating in a manner where pathogens could easily spread. The *cerrado* biome is undergoing one of the fastest conversion rates in Brazil, a situation where new forms of cross-species infections initiate (IUCN 2017). Agricultural systems such as rice paddies are fragile environments and susceptible to drastic fluctuations that negatively affect relationships between vectors and hosts (Bennet et al. 1982). Under these conditions, disease outbreaks could cause high mortality in a short period of time, potentially increasing the extinction risk of this population.

Classification and Conservation status of the Orinoco Goose. Threat categories and criteria address the risk of extinction of a taxon and seek to predict the probability of a species becoming extinct in the near future, based on the current knowledge of population trends, geographic distribution, and recent, current or projected threats (ICMBio 2013). Throughout its distribution, the Orinoco Goose was included in several red lists that cover different scales (Table 1). Unfortunately, the state of Tocantins lacks a list of endangered species, but the information presented here allows us to outline the threat status of the Orinoco Goose for the state and to represent a basis for future comparisons. The Orinoco Goose population for the Middle Araguaia (Cantão and Bananal Island region alone) was estimated at 2,000 to 4,000 individuals before 2007 (IUCN 2020). The Araguaia National Park was thought to support between 8% and 40% of the world's total population (Birdlife 2016), making this region one of the most important for the species' conservation. The data of the present study indicates a maximum population of about 1,000 individuals for the same area, demonstrating that in an

interval of ten years there has been a reduction between 50% and 75% of the population. In addition, much of the population is concentrated seasonally to a high degree and may include birds breeding outside the area. While it is difficult to estimate variability and errors of the earlier estimates, given our repeated measures over several years, it is very likely that the population decreased at or above the threshold of a 50% reduction used for a threat classification of Endangered (IUCN 2017).

Overall, our study depicts a population in serious decline relative to prior assessments and sheds light on a little-known seasonal aggregation in rice fields during the rainy season. The population decline alone is, unfortunately, of sufficient size to suggest that the population deserves to be considered as Endangered. Despite the presence of two fully protected conservation units in the Bananal Island region, Araguaia National Park and Cantão State Park, it is clear that the protection of the Middle Araguaia population of the Orinoco Goose is only protecting the population through a portion of its annual cycle. The protected areas do protect the species during the important periods of reproduction and post-reproductive molt between June and November. However, with the beginning of annual flooding in the region, the Orinoco Goose population moves outside of the protected area system and concentrates where rice is grown, specifically in the municipality of Lagoa da Confusão (Tocantins). These results conform with Tubelis' (2020) suggestion of likely migration within the Tocantins-Araguaia hydrographic region, and future tracking work will help illuminate the scale and details of those movements. Since Google Earth satellite images indicate that the first irrigated rice farms in Lagoa da Confusão municipality arrived around 1984, this movement pattern is unlikely to have been the case prior to cultivation of rice in the region. With the advent of this new regional land-use, and the seasonal concentrations we report, several concerns for the long-term conservation of the population emerge, and much more monitoring of populations in the region is recommended. Birds that use agrosystems intensively face several threats, both from direct and indirect causes. For the Orinoco Goose, these include the increased likelihood of disease outbreaks and potential illegal control, as is known from elsewhere in Brazil.

Due to the extreme population reduction observed in the last 10 years, significant seasonal concentrations of the population in a small, unprotected region, as well as a low estimated population size under changing movement patterns and potential threats linked to the management of agrosystems, the Orinoco Goose is at significant risk of extinction, at least at the state level, requiring its official recognition as a species threatened with extinction in the State of Tocantins. The information presented here suggests that the species be placed in the category Endangered. In addition, it is necessary to elaborate an action plan for the conservation of the Orinoco Goose in the surroundings of Bananal Island and in Brazil, where the threat status of the species must be reassessed. Considering that the Middle Araguaia River is recognized as one of the main areas for the preservation of the species in the country and in the world, closer monitoring and conservation efforts will be required.

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