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Authors: Pichorim, Mauro, Câmara, Thanyria Pollyneide França, de Oliveira-Júnior, Tonny Marques, de Oliveira, Damião Valdenor, Nascimento, Érica Patrícia Galvão do, et al.

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Research Article

A population of Blue-winged Macaw *Primolius maracana* in northeastern Brazil: recommendations for a local Conservation Action Plan

Mauro Pichorim[1], Thanyria Pollyneide França Câmara[1], Tonny Marques de Oliveira-Júnior[1], Damião Valdenor de Oliveira[1], Érica Patrícia Galvão do Nascimento[2] and Jason Alan Mobley[3]

[1] Universidade Federal do Rio Grande do Norte, Departamento de Botânica, Ecologia e Zoologia, Campus Universitário, Lagoa Nova, CEP 59078-900, Natal - RN, Brazil.

[2] Universidade Potiguar, Av. Senador Salgado Filho, 1610, Lagoa Nova, CEP 59056-000, Natal - RN, Brazil.

[3] AQUASIS - Associação de Pesquisa e Preservação de Ecossistemas Aquáticos, Avenida José de Alencar, 150, CEP 61627-010, Caucaia - CE, Brazil.

Corresponding author: Mauro Pichorim, e-mail: mauropichorim@yahoo.com.br

Abstract

The Blue-winged Macaw (*Primolius maracana*) is currently classified as near threatened, and studies have shown a decrease in its population size in the southern and northeastern limits of its distribution over the last 50 years. In this study we assess the current status of a local population in Northeastern Brazil and propose a conservation action plan. We visited 56 localities in the Serra de Santana mountain range to search for direct and indirect evidence of the species' presence or absence. We recorded *P. maracana* at 27 locations, restricted to two main areas (Pimenteira-Rio Fundo and Serra da Arara-Serra de São João). There was a positive correlation between the age of reported sightings and flock size ($r_s = 0.3$; $p = 0.02$), suggesting a decreasing population size over the last several decades. *P. maracana* breeds during the rainy season (December-May) in this region, and nests were recorded in mulungus, cumarus and craibeiras trees. Based on soil use criteria, plant cover, fauna use, and indicator species, hillside habitats have been less impacted than flat areas in the upper highlands (mean conservation for high flat area = 5.8 ± 2.0 and for hillside areas = 8.0 ± 2.1; $t_{53} = 3.96$, $p < 0.01$). The data indicate that Pimenteira-Rio Fundo and Serra da Arara-Serra de São João are priority areas for local conservation actions and that *P. maracana* is adapted to the hyper-xerophilous caatinga, and not restricted to the peripheral formations of this environment, as previously suggested. We propose measures to control the population decline, establish conservation units, implement tourism programs, adopt responsible environmental practices, and increase public awareness and mobilization. Such actions must be implemented by local government and civil society entities, university researchers, and landowners in order to be effective.

Keywords: Psittacidae, caatinga, nest poaching, Serra de Santana.

Resumo

A maracanã-verdadeira (*Primolius maracana*) é atualmente considerada quase ameaçada e estudos indicam diminuição no tamanho populacional ao longo dos últimos 50 anos nos limites sul e nordeste da sua distribuição. Neste trabalho, avaliamos o estado atual de uma população no Nordeste do Brasil e propomos um plano de ação para a sua conservação. Visitamos 56 localidades na Serra de Santana em busca de evidências diretas e indiretas da presença ou ausência da espécie. Registramos *P. maracana* em 27 localidades, restritas a duas áreas principais (Pimenteira-Rio Fundo e Serra da Arara-Serra de São João). Houve uma correlação positiva entre a idade das observações relatadas e o tamanho do bando (rs = 0,3; p = 0,02), o que sugere uma diminuição populacional ao longo das últimas décadas. Observamos a ocorrência de reprodução durante a estação chuvosa com ninhos sendo construídos em mulungus, cumarus e craibeiras. Com base em critérios de uso do solo, cobertura vegetal, uso da fauna e espécies indicadoras, detectamos que as áreas de encostas estão menos impactadas do que as áreas planas do alto da serra (índice de conservação das áreas planas = 5,8 ± 2,0 e das áreas de encostas = 8,0 ± 2,1; $t_{53} = 3,96$; $p < 0,01$). Os dados indicam que Pimenteira-Rio Fundo e Serra da Arara-Serra de São João são áreas prioritárias para ações de conservação locais e que *P. maracana* é adaptada para a caatinga hiper-xerófila, não sendo restrita às formações periféricas deste ambiente como previamente sugerido. Propomos como medidas de controle do declínio da população a criação de unidades de conservação, implementação de programas de turismo, adoção de práticas ambientais responsáveis, e o aumento da consciência pública e mobilização. Tais ações só serão eficazes se forem implementadas por entidades do governo local e da sociedade civil, pesquisadores de universidades e proprietários de terras.

Palavras-chave: Psittacidae, caatinga, captura ilegal, Serra de Santana.

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Introduction

The Family Psittacidae is one of the most endangered groups of birds in the world, with at least 28% of its species at risk of extinction [1]. Since the 1500s, nine Psittacidae species have gone extinct in the Neotropical region alone [1, 2]. Habitat loss, naturally reduced populations, introduction of predators and competitors, hunting, and illegal egg gathering are the main factors that threaten this group [1, 3].

Historically, *P. maracana* has been reported in 19 different states in Brazil, seven departments in Paraguay, and two provinces in Argentina. Today the species is considered extinct in Argentina, Rio Grande do Sul, and Santa Catarina in southern Brazil, critically endangered in Paraguay, and rare in the states of Paraná and São Paulo [4-13]. By contrast, in Rio de Janeiro, where *P. maracana* was considered to be most likely extinct [14], a portion of the state has been recolonized since the 1980s with an apparently increasing population [15]. The species is best characterized as a generalist with respect to habitat, occupying humid, semideciduous, deciduous, and dry forests, and occurring primarily at forest borders, near rivers, and even in areas dominated by human activities [4, 5]. Despite its widespread distribution and broad ecological niche, *P. maracana* is currently considered to be near threatened [5]. Studies have shown a decrease in its population size over the last 50 years in the southern and northeastern limits of its original distribution [4, 6].

There are numerous historical records of *P. maracana* in the states of Piauí, Maranhão and Bahia before 1980, and more recently in Ceará, Alagoas, Pernambuco, Maranhão, Piauí, and Bahia in northeastern Brazil [5]. In general, little is known about the ecology and habitat use of *P. maracana* in this unique semiarid region of the Brazil, which is dominated by a mosaic of scrub vegetation and patches of seasonally dry forest called caatinga. Knowledge about the species' behavioral ecology in the caatinga is restricted to its distribution in this region. These data alone are insufficient to assess the species' population stability in this ecoregion, and isolated records might conceal the true status of the population, which may very well be threatened and/or declining [16]. It is important to know the ecological parameters of this species in the northeastern limit of its distribution, given the severe degradation of the caatinga (60% altered) and general lack of specific attention to this region by conservationists [17, 18]. The aims of the current study were to assess the population status of *P. maracana* in the region of Serra de Santana, determine certain aspects of its ecology, and develop a local action plan for its conservation. The article is organized as follows: review of the sites where the species is currently known to occur in the region; observations of behavior and biological requirements associated with feeding and reproduction; assessment of conservation threats; proposal for priority areas, and a series of measurements that are necessary for conservation of the species in the region in the form of an action plan.

Methods

Study area

The Serra de Santana is a mountain range located in the south-central part of the state of Rio Grande do Norte, in northeastern Brazil (Fig. 1). The climate is semiarid, with mean annual rainfall between 400 and 600 mm, and hyper-xerophilous caatinga vegetation. The Serra de Santana has an elongated shape in an east-west direction, extending for approximately 40 km, and may be characterized as a sedimentary, plateau-like formation with heavily eroded slopes.

Fig. 1. Studied area in the Northeast Brazil for a Conservation Action Plan for the Blue-winged Macaw (*Primolius maracana*). The dark grey areas show the current occurrence of the species, and in the light grey areas the species is possibly extinct or extirpated (adapted from BirdLife International 2013). The black rectangle of the South America map is shown in detail below, and the white rectangle in the Rio Grande do Norte State represents the area surveyed (see Fig. 2).

Field procedure

We divided the Serra de Santana area into 17 sampling quadrants of 5' latitude x 5' longitude (~ 8,540 ha) to standardize the inventory effort (Fig. 2). We visited forest fragments in each quadrant using aerial images as reference. Conventional bird survey methods including active auditory and visual searching, playback, and listening points were employed. Observations were recorded using 10 x 42 binoculars and a digital camera fitted with a 300 mm lens. We also collected secondary data by interviewing local residents regarding the presence of the species in the vicinity and about their awareness of any hunting and/or capturing of the birds.

Between October 2009 and October 2010, we visited each quadrant over the course of ten separate fieldwork outings consisting of four to five days each. In total, 56 sites were surveyed within nine different municipalities, including Lagoa Nova, Bodó, Santana do Matos, Florânia, Cerro Corá, São Vicente, Tenente Laurentino Cruz, São Tomé, and Lages Pintadas (see Appendix 1).

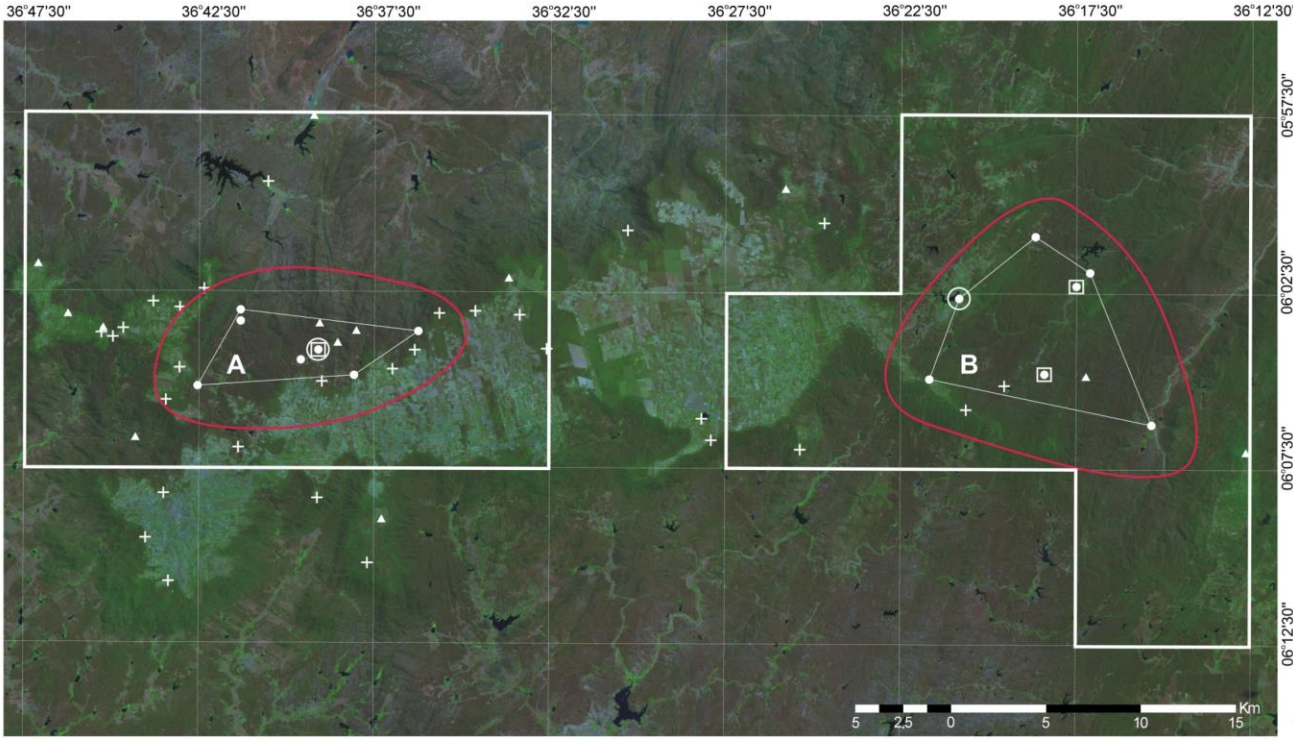

Fig. 2. Sites sampled and priority areas for Blue-winged Macaw (*Primolius maracana*) conservation in Serra de Santana, Northeast Brazil. The polygons A (Pimenteira-Rio Fundo) and B (Serra da Arara-Serra de São João) contain the recent records of the species and the red areas (2.5 km surrounding each polygon) are proposed as priority to establish protected areas. The quadrants of 5' latitude and longitude highlighted with white border must be a priority for environmental education, inspection, *in-situ* conservation, management and monitoring of fauna and flora. Each symbol corresponds to a place visited between 2009 and 2010 (△: old interview record - between 3-30 years, ○: recent interview record - last three years, □: direct observation in the field, ◯: individual observed in captivity, +: without record).

The total sample area encompassed 101,000 hectares. The minimum and maximum altitude in the study quadrants was 145 meters and 754 meters, respectively. Sites with some evidence of the presence of the focal species, as reported during interviews, were surveyed first. Occurrence was considered "recent" when the interviewee reported observing the birds within the last three years and "old" when an observation occurred between three and 30 years ago. For each occurrence we recorded the geographic coordinates, flock size, flight direction, landing site, time of day, and any interactions with other species or associated behaviors.

Observations of perched or foraging individuals included identification of the tree species being used by the birds. Evidence of reproduction identified in the field and/or reported during interviews was investigated more closely in order to assess reproductive seasonality and nest site characteristics. At each sampling point we filled out a standardized data form to detail habitat condition, using criteria related to soil use, plant cover, fauna use, and indicator species. Each of the habitat criteria was qualified on a scale of 0-3, where "0" represents areas in poor condition or with low biological value and "3" represents well-preserved areas with high environmental quality. Thus, for "soil use" we estimated the percentage of land compromised/impacted by agriculture, grazing and deforestation (0 = up to 100% in use; 1 = up to 75%; 2 = up to 50%; 3 = up to 25%). For "plant cover" we considered the physiognomy of existing native vegetation (0 = with no native vegetation;

1 = initial stage of regeneration; 2 = secondary; 3 = primary). For "fauna use" we considered the number of reports with some evidence of hunting and/or capturing of birds (0 = several reports; 1 = up to four reports; 2 = up to two reports; 3 = no report). For "indicator species" we considered the presence of trees known to be used by *P. maracana* for nesting and/or feeding (0 = absence; 1 = not common; 2 = common; 3 = abundant). The scores for each criterion at each sampling site were then summed to obtain the final quantitative value representing its conservation status (maximum score = 12).

Data analysis

We used a Pearson Correlation between the age of flock records (interviews and direct observations) and the number of birds per flock reported or observed, to test whether there were any changes in flock size during the last 30 years. To compare the state of habitat preservation between slopes and higher elevation plateau areas, we used a t-test comparing the mean conservation score of the sites from each area. We considered recent records of the species' presence and the current state of preservation of each site to determine priority areas for conservation and propose measures related to management, inspection and environmental education. The scientific and common names used here follow BirdLife International's taxonomic checklist [19].

Results

Occurrence

We recorded *P. maracana* at 27 localities in 12 of the 17 quadrants sampled at 5' latitude and longitude (Fig. 2). Considering all of the interviews with local residents who reported having observed *P. maracana*, recent accounts (33 observations in the last three years) indicated flocks of up to 15 individuals, while older accounts (26 observations occurring more than three years ago) indicated flocks of up to 30 individuals (Table 1, Fig. 2). We found a positive correlation between the age of records and flock sizes ($r_s = 0.3$; $p = 0.02$, Fig. 3). All local residents who reported observations were unanimous in stating that flocks had been larger (5-30 birds) in the past (3-30 years ago). Considering only direct observations and reports from interviews up to three years ago, the species was restricted to two areas, encompassing 14 localities. The first of these areas is Pimenteira-Rio Fundo (sites 1, 4, 16, 19, 22, 23 and 24), and the second is Serra da Arara-Serra de São João (sites 47, 48, 49, 50, 53, 54 and 56). We confirmed the species presence by visual observation in Pimenteira-Rio Fundo (1 observation) and Serra da Arara-Serra de São João (13 observations between June and October) (Table 2). We did not visit the second area outside of this time frame, but local residents were unanimous in stating that the species occupied the surrounding areas throughout the year.

According to the habitat assessment we performed, based on soil use criteria, plant cover, fauna use, and indicator species, sloped areas are better preserved than flat areas in the upper highlands (mean conservation for high flat area = 5.8 ± 2.0 and for hillside areas = 8.0 ± 2.1; $t_{53} = 3.96$, $p < 0.01$). The highest conservation values obtained for high flat areas were eight and nine (sites 6, 27, 34, 44, 46 and 55), while for sloped areas they were ten and 11 (sites 7, 12, 17, 22, 23, 48, 49, 50, 51 and 52). The sites in the areas known as Pimenteira-Rio Fundo and Serra da Arara-Serra de São João showed a high mean index for state of preservation (6.3 ± 1.1 and 7.8 ± 3.2 respectively), and these areas accounted for 75.4% of the interview reports (Table 1). The minimum convex polygons formed by the Pimenteira-Rio Fundo and Serra da Arara-Serra de São João sites encompass 2,850 ha and 6,500 ha, respectively (Fig. 2, Appendix 1).

Feeding

We observed *P. maracana* feeding on facheiro cactus (*Pilosocereus pachycladus*, Cactaceae) on two occasions (June 2010, site 49, Fig. 4D) and once on fruits of the aroeira tree (*Myracrodruon urundeuva*, Anacardiaceae, October 2010, site 49, Fig. 4F). The local residents reported that *P. maracana* feeds on at least nine different plant species in Serra de Santana (Table 3). In addition to these reports, we identified nine other plant species bearing apparently good quality fruits for macaws and parrots (Table 3). In the middle of the dry season (October) we observed aroeira trees with flowers and fruits and craibeira trees (*Tabebuia aurea*, Bignoniaceae)

with flowers, while mulungu trees (*Erythrina velutina*, Fabaceae) had pods with green seeds, all potential food resources suitable for *P. maracana*. No other trees exhibited fruits or flowers during the dry season, and their leaves were already dry and/or had fallen.

Reports of *P. maracana* feeding on cotton are particularly interesting, because older residents stated that the crop was much more important in the past throughout the entire region. According to these interviewees, macaws eat the flower buds, which are known locally as "casulo da flor do algodão" (cotton flower cocoon). In addition to the aforementioned food resources, one resident from site 49 reported observing flocks of *P. maracana* in a nearby region denominated as salitre, where birds apparently eat the clay found there. However, this same respondent never actually saw macaws eating this material at the site and had merely heard about it from other residents. We did not visit the area to further assess this observation.

Table 1 Records of Blue-winged Macaw (*Primolius maracana*) from interviews with local citizens of Serra de Santana region, Northeast Brazil between 2009 and 2010 (in parenthesis the number of birds reported by interview).

Localities	Number of recent observations (last three years)	Number of old observations (between 3-30 years)
Pimenteira-Rio Fundo	18 (1-4)	6 (1-10)
Serra da Arara-Serra de São João	14 (1-15)	5 (1-20)
Others	0	14 (1-30)

Reproduction

We documented evidence of old and recent nesting activity, indicating that Serra de Santana is a resident area for *P. maracana*. The first record of reproduction was for a single nestling captured at site 7 and raised in captivity by a resident of Sítio Pimenteira (site 1). There is no evidence for the month this individual was captured, just that it was removed from a nest located in a mulungu tree during the rainy season around 15 years ago. The site where this bird was captured can be characterized as arboreal caatinga, where certain tree species, such as angico (*Anadenanthera colubrina*, Fabaceae), aroeira and mulungu, are quite tall (~15 m) (Table 3). We counted 19 large mulungu trees, including the same tree from which the bird itself was removed, as evidenced by a nest cavity that was clearly compromised with a hatchet or machete at some time. The trees at this site ranged in height from 10-15 m and in diameter at breast height from 50-80 cm. Five trees had visible natural cavities that were most likely occupied by Crimson-crested Woodpecker (*Campephilus melanoleucos*). Ten other trees had larger cavities that would be more suitable for *P. maracana*. Two of these cavities appeared new, with grooves at the edges of the entrance, but the rest looked to be old and unoccupied. Although we surveyed this area during the rainy and dry seasons, no *P. maracana* individuals or any other concrete signs of these cavities being used were observed.

Table 2 Observation records of Blue-winged Macaw (*Primolius maracana*) in the Serra de Santana, Northeast Brazil between 2009 and 2010.

Date and time (dd/mm/yyyy)	Site	Birds observed
17/10/2009, 06:15	01	1 [a]
26/06/2010, 07:20	49	2 [b]
26/06/2010, 16:20	49	6 [c]
27/06/2010, 15:40	49	4 [c]
28/06/2010, 05:32	48	2 [d]
28/06/2010, 06:17	48	2 [d]
28/06/2010, 08:44	48	2 [e]
03/08/2010, 07:20	49	2 [c]
03/08/2010, 07:40-08:30	49	18 [c]
03/08/2010, 09:30	49	10 [c]
03/08/2010, 17:00-17:10	49	14 [c]
09/10/2010, 16:12-17:24	49	16 [c]
10/10/2010, 04:50-07:52	49	23 [c]
11/10/2010, 04:30-08:00	49	6 [b]

[a] Flying over caatinga (3-5 m) of hillside with agriculture and cattle.
[b] Flying over a valley with a broad dry river on occasion and with fruit trees and abandoned houses in the surroundings.
[c] Flying over caatinga (5-12 m tall) impacted by overgrazing, selective vegetation clearing, and hunting.
[d] Flying over caatinga (5-10 m tall) of undulating terrain with agriculture and cattle.
[e] Flying over valley with agriculture, fruit trees and some houses in the surroundings.

A second resident of Sítio Pimenteira claimed to have removed a *P. maracana* nestling from a mulungu tree at site 23 during the rainy season in 1986, raised it, and kept in captivity until it died. Further testimony informed us that the following year, a pair of *P. maracana* nested in the same cavity and that the nestlings were captured by other residents, who also cut down the tree. These are the only two sites where reproduction of the species was confirmed in Sítio Pimenteira-Rio Fundo (Fig. 2 - Polygon A).

In Serra da Arara-Serra de São João we documented five reports of breeding activity, two in cumaru trees and three in mulungu trees. One resident was able to show us a cumaru tree at site 49 from which two nestlings were removed in early 2002, although the exact month is unknown. This tree was ~12 m high, with a diameter at breast level of 40 cm. The nest cavity was located on the underside of a slightly inclined branch 8 m above ground, with a 15 x 18 cm opening. There was also evidence at this site of *P. maracana* having used another cumaru tree in March 2010, according to testimony that residents had captured two nestlings there (Fig. 4l). This tree measured 9 m high, with a diameter at breast level of 40 cm. The nest cavity was located 5 m above ground, with a downward-sloping opening measuring 10 x 10 cm, well protected from the rain. The perimeter of the trunk at the height of the entrance was 97 cm and the nest cavity was 81 cm deep. The resident told us that chicks had been removed from this same nest for at least the previous three years. Adult feathers, down, and dry feces were collected from the nest, confirming recent activity. We also observed a smaller opening in the trunk, 30 cm below the nest entrance, which led directly to the inside of the cavity and from which the brood was likely monitored until being removed.

We documented two other reports of nests at site 50, one regarding an old *P. maracana* nest in a mulungu tree that had been cut down three years before, and another nest from four years earlier, also in a mulungu tree, but near a river in a deep valley. Since the interviewee had not returned to the site since then, he could not confirm if the nest was still active. Neither resident was able to recall the exact months during which these nests were active only that it was during the rainy season.

The last report of a nest in Serra da Arara-Serra de São João occurred at site 48. With the help of a local resident, we were able to examine three mulungu trees and one cumaru tree with cavities apparently suitable to the focal species, but breeding activity was only confirmed for one of the mulungu trees, which was 12 m high, with a diameter at breast level of 40 cm, one cavity at 5 m and another at 7 m. Testimony indicated that the higher cavity had been used 15 years ago by *P. maracana* and that local residents removed the chicks,

although the exact month of this event was not known. We also recorded six other mulungu and two cumaru trees in Serra da Arara-Serra de São João with cavities whose dimensions were compatible with *P. maracana*, although we could not confirm any evidence of reproductive activity.

Considering all of the sites visited, cavities suitable for *P. maracana* were located in 29 mulungu, four cumaru and two craibeira trees (Fig. 4). These trees measured 13.7 ± 4.0 m high on average (ranging 9-20 m) with a mean diameter at breast level of 55.5 ± 20.6 cm (ranging 30-110 cm). In addition to the appropriated cavities to *P. maracana*, some of these trees had also smaller cavities likely occupied by woodpeckers. Possible *P. maracana* nest cavities were located 7.9 ± 4.1 m above ground on average (ranging 4-17 m) and exhibited a circular or oval-shaped opening with a mean horizontal diameter of 12.5 ± 1.9 cm (ranging 10-15 cm) and a mean vertical diameter of 13.9 ± 2.9 cm (ranging 10-18 cm). These trunks or branches (diameter 25-30 cm) in which the cavities were located were slightly inclined, with a downward facing entrance.

Table 3 Plants used by Blue-winged Macaw (*Primolius maracana*) as food resource in the Serra de Santana, Northeast Brazil (information obtained through direct observation and/or interviews with local residents between 2009 and 2010).

Species (vernacular name)	Family	Source
Myracrodruon urundeuva (aroeira)	Anacardiaceae	Observation and interview
Pilosocereus pachycladus (facheiro)	Cactaceae	Observation
Schinopsis brasiliensis (braúna)	Anacardiaceae	Interview
Anacardium occidentale (cashew)	Anacardiaceae	Interview
Spondias tuberosa (umbuzeiro)	Anacardiaceae	Interview
Commiphora leptophloeos (imburana)	Buseraceae	Interview
Manihot glaziovii (maniçoba)	Euphorbiaceae	Interview
Jatropha mollissima (pinhão)	Euphorbiaceae	Interview
Gossypium sp. (cotton)	Malvaceae	Interview
Zea mays (corn)	Poaceae	Interview
Tabebuia aurea (craibeira)	Bignoniaceae	Possibility
Amburana cearensis (cumaru)	Fabaceae	Possibility
Erythrina velutina (mulungu)	Fabaceae	Possibility
Syagrus cearensis (catolé)	Arecaceae	Interview
Ziziphus joazeiro (joazeiro)	Rhamnaceae	Possibility
Anadenanthera colubrina (angico)	Fabaceae	Possibility
Prosopis juliflora (mesquite, algaroba)	Fabaceae	Possibility
Hymenaea courbaril (jatobá)	Fabaceae	Possibility
Caesalpinia pyramidalis (catingueira)	Fabaceae	Possibility
Licania rigida (oiticica)	Chrysobalanaceae	Possibility

Threats and environmental impacts

The Serra de Santana is impacted almost entirely by grazing, selective wood extraction, clearing of vegetation, and intense hunting pressure. Cashew and cassava plantations, slash-and-burn agriculture and urbanization have most significantly altered the areas located in elevated and flat parts of the Serra de Santana. According to local residents, these places are more propitious for agriculture, and they have been systematically deforested over the last 30 years by settlers enrolled in National Institute for Colonization and Agrarian Reform (INCRA) programs. We visited various settlements where recent vegetation cutting and slash-and-burn activity was confirmed (Fig. 5A and B). Areas of sloped terrain are less impacted, although many places display the impacts of grazing and selective wood removal, ranging from moderate to intense levels of activity (Fig. 4 A and B).

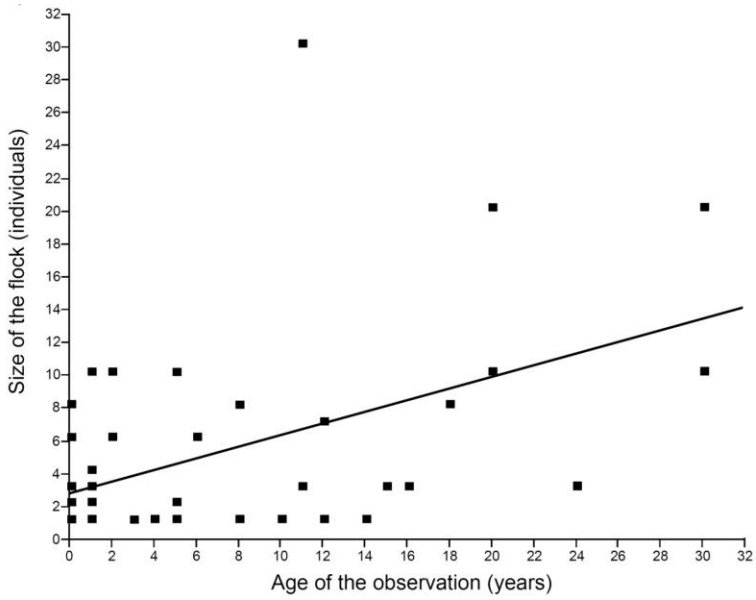

Fig. 3. Positive correlation between the observed flock size of Blue-winged Macaw (*Primolius maracana*) and age of the observation related by interviews with local citizens of Serra de Santana between 2009-2010, Northeast Brazil (r_s = 0.3; p = 0.02).

We encountered three individual *P. maracana* that had been captured in the region and were being raised in captivity. The first individual was observed at the house of a resident from site 1 who has kept the animal for 15 years since he removed it from a mulungu tree at site 7 (Fig. 5C). A 14 year old bird located at the house of a resident in the city of Cerro Corá (site 53), was said to have been removed from a nearby nest (Fig. 5D). Another captive individual discovered in Cerro Corá (Fig. 5E) was bought as a chick for US$ 25.00 about four years ago, along with a second individual that escaped a year later. These birds were said to have been captured in Serra de São João. There was also a report of an individual *P. maracana* raised in captivity in the city of Santana do Matos that had died 13 years before.

In addition to these few direct accounts of the capture and sale of *P. maracana*, it was clear that keeping wild birds in cages is a very common local practice; we recorded being kept as pets Blue-winged Parrotlets (*Forpus xanthopterygius*), Cactus Parakeets (*Aratinga catorum*), Picazuro Pigeons (*Patagioenas picazuro*), Eared Doves (*Zenaida auriculata*), Plain-breasted Ground-Doves (*Columbina minuta*), Scaled Doves (*Columbina squammata*), Picui Ground-Doves (*Columbina picui*), Blue Ground-Dove (*Claravis pretiosa*), Bananaquits (*Coereba flaveola*), Ultramarine Grosbeaks (*Cyanocompsa brissonii*), Red-cowled Cardinals (*Paroaria dominicana*), White-throated Seedeaters (*Sporophila albogularis*), Pileated Finches (*Coryphospingus pileatus*), Chopi Blackbirds (*Gnorimopsar chopi*), and Campo Troupials (*Icterus jamacaii*). Street fairs in the cities of Jucurutu, Florânia and Currais Novos are all known to have birds for sale, although no *P. maracana* were confirmed. When we visited the street fair in Florânia no one was selling birds, although interviews with three people at the market indicated that pairs of Yellow-faced Siskins (*Carduelis yarrellii*) are regularly sold for US$ 300.00 in Tenente Laurentino Cruz. Unfortunately, capturing wild animals and raising them in captivity is a common practice, not only with respect to birds; we also saw a Jaguarundi cub (*Puma yagouaroundi* rufous morpho) and a Black-striped Capuchin (*Cebus libidinosus*) being raised in captivity (Fig. 5 G, H).

During all fieldwork periods, signs of wildlife-hunting were detected visually or through interviews. Hunting pressure is particularly worrisome in the eastern portion of Serra de Santana (Serra de São João and Serra da Arara mountain ranges). Given that this area has more preserved vegetation, it still harbors the game species that are increasingly rare or even locally extinct in other parts of the region. One resident from site 50 reported having killed more than 70 South American Brown Brockets (*Mazama gouazoubira*) in the 1970s, sometimes more than one individual per month. He also reported that it was still possible to hunt White-browed Guans (*Penelope jacucaca*, a threatened species [1, 20]) and other birds. At site 48 we witnessed the capture of a Six-banded Armadillo (*Euphractus sexcinctus*) and at site 49 a local citizen claimed to have killed three Cougars (*Puma concolor*) near his house 30 years ago. Moreover, he said that people from other municipalities go to

this area just to hunt Six-banded Armadillos, Southern Tamanduas (*Tamandua tetradactyla*), White-browed Guans, and various species of Tinamou (*Crypturellus* spp.).

Priority areas for conservation

Survey efforts indicated that the Pimenteira-Rio Fundo area (Fig. 2 - Polygon A) currently shows a sporadic presence of *P. maracana*, although its historical frequency of occurrence there was probably greater, as evidenced by old records of nesting behavior. On the other hand, there have been several recent visual records and confirmed accounts of breeding in Serra da Arara-Serra de São João (Fig. 2 - Polygon B). Environmental assessments tell us that these polygons are characterized by moderately preserved caatinga with impacts restricted to grazing and selective cutting in the best areas of the region and also include a number of plant species important for both feeding and breeding to *P. maracana*.

We recommend that these two areas, along with a 2.5 km area adjacent to them, be defined as priority areas for the conservation of *P. maracana* in Serra de Santana and be afforded complete protection under federal law. Each of the polygons is located within six 5' x 5' quadrants of latitude and longitude and should be given high priority for promoting environmental education, inspection, *in-situ* conservation, management, and monitoring of fauna and flora throughout Serra de Santana. We highlight the polygon "B" quadrants, due to the larger population of *P. maracana* and more recent records there (Fig. 2). It is important to emphasize that we visited other areas that should also be considered equally significant, principally due to positive reports of the species' presence and important fragments of caatinga remaining on the high flat portion of the highlands. Such places tend to suffer the most direct impacts of deforestation, so this particular locality is unusual since it is an elevated area with endemic, threatened and rare species of caatinga avifauna. In the few fragments of mature caatinga habitat on the plateau, we observed White-bellied Nothuras (*Nothura boraquira*), White-browed Guans (*Penelope jacucaca*), Ochraceous Piculets (*Picumnus limae*), Silvery-cheeked Antshrikes (*Sakesphorus cristatus*), Red-shouldered Spinetails (*Gyalophylax hellmayri*), Scarlet-throated Tanagers (*Compsothraupis loricata*) and Yellow-faced Siskins (*Carduelis yarrellii*).

Actions developed

We presented these findings and a proposal for conservation actions directed at *P. maracana* to the municipal governments of Santana do Matos and Cerro Corá, the Institute for the Sustainable Development of the Environment (IDEMA), and the Brazilian Institute for the Environment and Renewable Resources (IBAMA). On 14 April 2011 we met with the mayor of Santana do Matos, Mr. Francisco de Assis Silva, and stressed the importance of the local government prohibiting the capture of wild animals, hunting, and vegetation clearing in areas of permanent preservation (APPs), in addition to the need for regulating other pressures observed in the rural areas of the municipality. On the same day, we also met with the Secretary of Agriculture, Environment and Tourism of Cerro Corá, Mr. Francisco de Assis dos Santos. We explained the importance of maintaining a population of *P. maracana* in the region and underscored the importance of protecting these birds as a part of developing and promoting rural and ecotourism, which the municipality has been trying to stimulate in recent years. Furthermore, we requested that the capture of wild animals, hunting, and vegetation clearing also be strictly prohibited.

We participated in two meetings with the Institute for the Sustainable Development of the Environment of RN (IDEMA). The first took place on 12 May 2011 with the coordinator of NUPE (Center for Analysis and Environmental Licensing of Wind Farms), Mr. Iron de Medeiros Bezerra, and his team. This division of IDEMA analyzes and authorizes wind farm projects in the state of Rio Grande do Norte (RN). Since the Serra de Santana has been a focus area for implementing this type of initiative, some of which have already been licensed, our aim was to explain the importance of the region for fauna in general, especially caatinga formations in highland areas. We spoke about the need for installing wind farms far from the priority areas for *P. maracana* that have now been identified and also requested that specific studies be considered mandatory for each proposed installation with respect to the possible impacts on *P. maracana* in the region.

Finally, we discussed the possibility of requiring that the legal reserves areas of the rural properties with wind farms be defined on a co-ownership basis within one of the priority areas for *P. maracana* in the region, in order to ensure more immediate protection for these areas.

The second meeting with IDEMA occurred on 17 May 2011 with Mr. Flávio Henrique Cunha de Farias, coordinator of the Center for Management of Conservation Units in RN. At this time, we highlighted the need to create formal conservation units in the priority areas outlined by the current study. The state has recently implemented a number of measures to establish new conservation units (CUs) in the caatinga, so our presentation was important for the authorities to recognize the immediate possibility of establishing CUs in these areas.

A meeting with IBAMA representatives occurred on 16 May 2011 in the city of Natal, RN and was attended by the State Superintendent, Mr. Alvamar Costa de Queiroz, Assistant Superintendent, Mr. Robson Lopes de Santana, Chief Inspector, Mr. Alexandre Rochinski, and several wildlife technicians. We presented the results of our assessment, emphasizing the need for a sustained wildlife monitoring effort in the Serra de Santana region in order to enforce the prohibition of hunting, capture and trade of fauna. It was agreed that the priority areas will be targeted for more intense patrolling and that our team will accompany IBAMA technicians during future expeditions to Serra de Santana for an *in loco* inspection of priority areas for *P. maracana*.

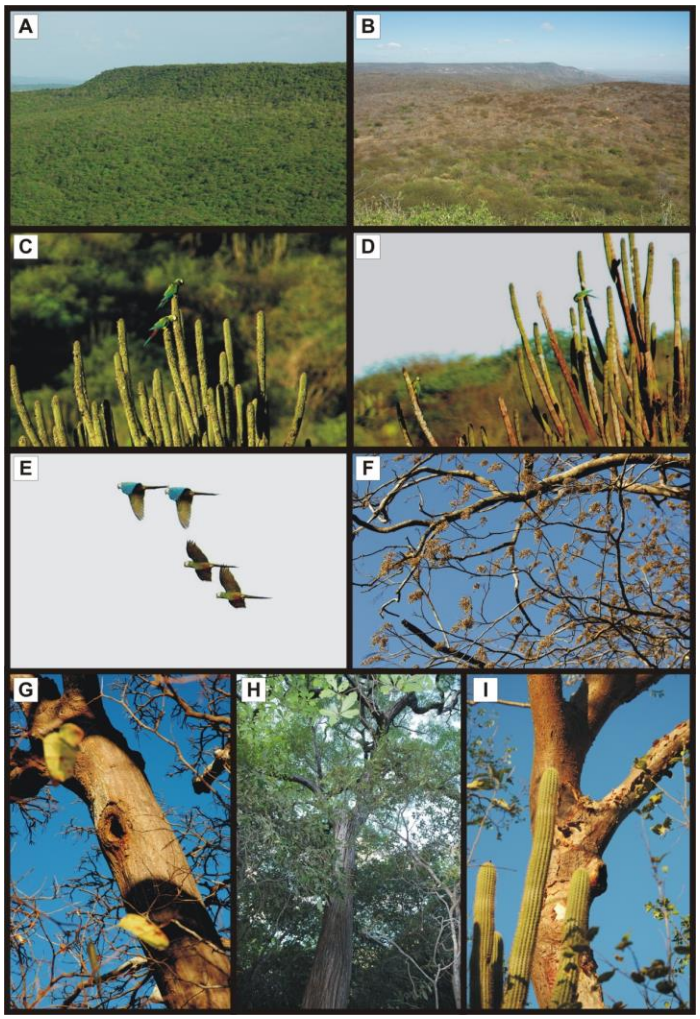

Fig. 4. General appearance of Serra de Santana, northeast Brazil and visual records of feeding and reproduction of Blue-winged Macaw (*Primolius maracana*) made in 2010. A and B: physiognomies of the terrain and vegetation in the rainy and dry seasons respectively; C, D and E: visual records made in Serra da Arara-Serra de São João (site 49, in D it is possible to see an individual eating the fruit of *Pilosocereus pachycladus*, Cactaceae); F: aroeira tree with flower (*Myracrodruon urundeuva*, Anacardiaceae) a local food item of *P. maracana*; G (mulungu *Erythrina velutina*, Fabaceae), H (craibeira *Tabebuia aurea*, Bignoniaceae) e I (cumaru *Amburana cearensis*, Fabaceae): trees normally used by *P. maracana* for nesting (in the last tree there was reproduction, but the nestlings were poached and sold by local citizens on march 2010).

Discussion

The observations reported here effectively increase the known distribution of *P. maracana* to the extreme northeastern part of Brazil, as the species had never been previously reported for the states of Rio Grande do Norte or Paraíba [4]. Furthermore, some of the evidence we collected suggests that the species has been present in this area for at least the past 30 years, indicating that colonization has not been so recent and that the species is well adapted to the hyper-xerophilous caatinga habitat, and not just restricted to the peripheral formations of the biome, gallery and/or deciduous forest, as previously thought [5]. Our observations point to the presence of *P. maracana* throughout the Serra de Santana, and suggest that it likely occurred in some adjacent areas with similar terrain and vegetation.

The southern portion of Rio Grande do Norte and northern Paraíba is a rocky, mountainous region known as the Seridó and contains food resources and possible nesting sites for the species in the deepest valleys and hillsides. Thus, it is likely that in the past *P. maracana* occupied other localities throughout the Seridó region, which covers around two million hectares and represents the probable limit of the species' historical distribution to the extreme northeast of Brazil. Comparing this hypothetical historical distribution to our observations of the current distribution of the species (~200,000 ha), we estimate that there has been a 90% reduction in the area that it occupies. It is important to emphasize, however, that we did not systematically search for *P. maracana* throughout the entire Seridó region. Thus, there may still be unknown remnant populations, which would further increase the extent of the species' currently known area of occurrence. However, even considering this possibility, the actual extent of potential occurrence does not exceed 500,000 ha in the Seridó region. Furthermore, the current area of occupation that we surveyed does not surpass 10,000 ha and the overall population size is probably fewer than 250 mature individuals. Considering IUCN red list categories and criteria, we recommend that in the Seridó region, this species should be classified as Critically Endangered according to criterion C2a(i, ii) and Endangered according to criteria B1b(i), B2b(ii, iii) and D.

The two areas of Serra de Santana with recent records of *P. maracana*, Pimenteira-Rio Fundo and Serra da Arara-Serra de São João, are better preserved and should be considered vital to the conservation of this population. The more important of these areas is the Serra da Arara-Serra de São João polygon, which appears to support more adult birds and has more evidence of recent breeding activity, but also more obvious threats to conservation. Additionally, this eastern portion of the Serra de Santana is a large and relatively preserved region of the caatinga, the undulating terrain is also unfavorable for agriculture, and there is already significant pressure from grazing and selective cutting. This area also receives more rainfall than the western side of the range and contains tree species that are known to be exploited by *P. maracana* and which may be used as indicators of environmental quality in maintaining populations of *P. maracana*.

The ecology of *P. maracana* in the caatinga was hitherto completely unknown, and basic information about the species' preferred food resources and reproductive behavior has been only sporadically reported in Brazil [1, 21]. *P. maracana* is a dietary generalist, but except for fewer than ten species of fruits, some of which are exotic, very little is known about the exact nature of its foraging habits throughout its entire distribution [5, 19, 22]. Our observations suggest that *P. maracana* utilizes some caatinga plant species, even in the dry season (see Table 3). For some of these species, it is still necessary to study the intensity of use and real nutritional value for *P. maracana*, as has been done for other Psittacidae [23-25].

New information about the foraging habits of *P. maracana* in the caatinga was also acquired through interviews regarding the use of cultivars such as corn and cotton. The latter is particularly interesting to consider, because cotton was an important crop between the 1950s and 1970s in Serra de Santana. It is highly likely that various Psittacidae species had enough impact on plantations that they were directly persecuted by farmers [19, 26]. In this respect, a better understanding of *P. maracana* diet in the Serra de Santana is important. The seasonal abundance of potential food resources also seems to vary widely throughout the Serra de Santana, which certainly has an influence on the species' occurrence in the region. We observed flowers and fruits in different stages of development during the dry season and occurring later in the eastern part of the region than in the western portion. When the vegetation in Serra da Arara-Serra de São João was

still green, other sites were completely dry. It seems that orographic rainfall in this region is most common and contributes to maintaining the *P. maracana* population.

P. maracana breeds in the Serra de Santana during the rainy season, between December and May. The testimony that chicks had been removed from a nest in March indicates that the eggs were laid in January. Less accurate reports indicate that offspring are born at the beginning of the year. There are reports of *P. maracana* breeding in northeastern Brazil from December through February [5] and in the northern region of Brazil in December [19]. Precise knowledge of the reproductive cycle of the species in each area of occurrence is important for implementing conservation measures to impede illegal capturing and optimize resources and field efforts.

We recommend that efforts to combat the illegal sale of *P. maracana* in the Seridó region be focused primarily between December and May. Interviews with residents suggest that two eggs are laid, given that the most reliable respondents never described the capture of more than two chicks. There are accounts of three eggs being laid in captivity, but no additional information on brood size is available for the species [19]. There is no evidence for more than one breeding attempt during the same reproductive season for *P. maracana*, although the species is known to remain in the vicinity of the nesting site between breeding seasons. Therefore, active nesting sites must be monitored daily from the first signs of breeding activity in order to prevent the capture of any nestlings. Constant monitoring of nests has been an essential part of successful conservation actions with other Psittacidae species [27] and will be crucial to conservation planning for *P. maracana* in Serra de Santana.

The tree species that *P. maracana* is known to use for nesting in Serra de Santana (mulungu, cumaru and craibeira) are common only in better preserved and more remote areas of the Seridó. The mulungu tree seems to be preferred, probably due to its soft wood and thick branches located high above the ground. This species is also not selectively harvested because it has no commercial value, while cumaru and craibeira are both exploited for various purposes. For these reasons, measures to combat clearing and burning practices, as well as to regulate selective cutting, must be implemented in the short term. Furthermore, the experimental installation of nest boxes could be very helpful in monitoring and increasing local reproductive output in a number of key areas, such as the Serra da Arara-Serra de São João polygon. We recommend the implementation of a pilot project that builds on the new knowledge presented here regarding the specific characteristics of natural cavities used by *P. maracana*.

With respect to the impacts and threats identified in the areas where *P. maracana* is known to occur in Serra de Santana region, we conclude that settlement programs instituted by the Federal Government (through INCRA) are the primary factor contributing to the rapid loss of local vegetation cover. Although these settlements include areas that are designated as legal environmental reserves, they are not respected and are being systematically altered, invaded by unauthorized occupants, and used to hunt and capture wild animals. It is crucial that the establishment of these settlements be accompanied by rigorous inspections, enforcement of the laws designed to protect reserve areas, and environmental education. It should also be emphasized that overgrazing is common in some parts of Serra de Santana and has already led to the onset of the desertification process. These areas must also be mapped and monitored, and should be subjected to habitat recovery efforts in especially degraded areas before they become irreversibly damaged.

Although subsistence hunting was a common and widespread practice in the region around 30 years ago, hunters now live mostly in the nearby cities and engage in the activity on weekends. There are also a few local hunters who are known to supply most of the demand for wild game from city residents. These people do not really depend on hunting for survival, and their illegal activities have not been challenged by the authorities responsible for law enforcement in the region. Immediate and severe measures are needed to preserve the local fauna. Populations of the species that are hunted and captured by wildlife traffickers are undoubtedly overexploited, and local extinctions of threatened fauna, such as *C. yarrellii*, are an imminent possibility. Regrettably, the illegal trade of wild birds is still widespread in South America and includes large numbers of different species, many of which have been confirmed to be locally extinct [28-31].

With respect to divulging our findings and promoting conservation actions, we must underscore the importance of sharing our results with local authorities and state and federal environmental agencies. This is an essential step in combating the continued loss of local biodiversity and implementing an action plan to recover *P. maracana* populations. Although our proposals have been generally well received, a lack of resources and organizational structure among local authorities precludes immediate action. Municipal governments in rural areas do not have the technical support to qualify environmental agents as inspectors or conduct environmental education campaigns. There is also a serious absence of environmental authorities willing to assume responsibility for these oversights, let alone to promote reform or proper enforcement.

Constant monitoring and the presence of environmental authorities are urgently needed to extinguish poaching and allow the species enough reproductive success to offset an apparently drastic population decline in the region. Although we did not document specific cases of illegal trade at the local fairs we investigated, there is little doubt that the population of this species has been seriously compromised. It may also be the case that nestlings removed from the wild are being purchased in more affluent cities in the region (e.g. Natal, Fortaleza, Recife), where they most certainly fetch a much higher price.

One of the greatest ongoing threats to the effective conservation of parrots and macaws is capture for commercial purposes [1-3, 19, 29, 30, 32, 33]. The evidence demonstrates that *P. maracana* is being illegally exploited in Brazil and that this single criminal activity is a principle cause of its serious population decline in the Serra de Santana. Continuous monitoring of threatened Psittacidae populations is practically nonexistent, despite being necessary for understanding basic population dynamics [1, 2].

Monitoring nests over the entire reproductive period, as with the Red-spectacled Amazon (*Amazona pretrei*) [34], is one possible way to ensure reproductive success to *P. maracana* in the study area. Artificial nest boxes should also be considered as a temporary means of intervention to compensate for the low availability of natural cavities. This method has proven to be effective in the recovery of populations of various species [26, 35].

Combating overall environmental degradation in the region must start with measures to ensure the enforcement of environmental legislation at rural settlements and private properties in the Serra de Santana. It is especially important to demand that the federal fauna law (5,197/1967) be enforced, as well as defining, maintaining, and respecting legal reserves and permanent preservation areas (law 12,651/2012). Habitat loss is a serious and ongoing threat to some of the most endangered parrot species in the Neotropics [1, 33]. Therefore, it is vital to prevent unnecessary losses in the Serra de Santana through strict control over inspection measures and a rigorous environmental licensing process for any proposed undertaking in the priority conservation areas defined for *P. maracana* in this study (polygons A and B in Fig. 2). Any potential threats to the species should be considered according to the principles of utmost precaution, and informed decisions must address the potential synergistic effects of all known impacts. Environmental licensing requirements must be stringent, with clear definitions of how any at-risk species will be protected.

For effective management and reintroduction of captured species, we suggest that research on reproductive monitoring, population dynamics, patterns of movement, and food resource dynamics for *P. maracana* is necessary. Basic research is an essential component in the conservation process of most threatened Psittacidae [1, 2, 19, 26]. Furthermore, estimates of genetic variability, inbreeding, and the effective size of wild populations are necessary for effective conservation planning and management [36, 37]. Genetic variability in *P. maracana* is low for unknown reasons; it may be due to a natural condition or to a reduced area of occurrence [38]. Biogeographic studies using niche modeling would also be useful in determining the potential distribution of *P. maracana* and could have direct implications on conservation planning [4, 33, 39, 40]. It is also important to continue updating our knowledge of the species' known areas of occupation and extent of geographic occurrence in the caatinga by using these techniques and coordinating more frequent field surveys.

Implementing the proposed legal measures is the responsibility of various federal, state, and municipal executive and legislative branches of the government, including the Ministry of the Environment (MMA), Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), Chico Mendes Institute for

Biodiversity Conservation (ICMBio), National Institute for Settlement and Agrarian Reform (INCRA), Public Ministry of Rio Grande do Norte, Legislative Assembly of Rio Grande do Norte, State Tourism Secretariat Institute for Sustainable Development and the Environment of Rio Grande do Norte (IDEMA), Environmental Military Police of Rio Grande do Norte, Independent Environmental Protection Company (CIPAM), and Municipal Secretariat for the Environment and Education. The overall conservation process here must also involve civil society organizations (non-governmental organizations - NGOs - and community associations), universities (Federal University of Rio Grande do Norte - UFRN - and Rural Federal University of the Semiarid - UFERSA), private landowners, and media organizations (newspaper, radio, television, and the internet). Only through the joint actions of all the stakeholders involved will it be possible to implement the necessary measures and effectively oversee the conservation of *P. maracana* in the Serra de Santana.

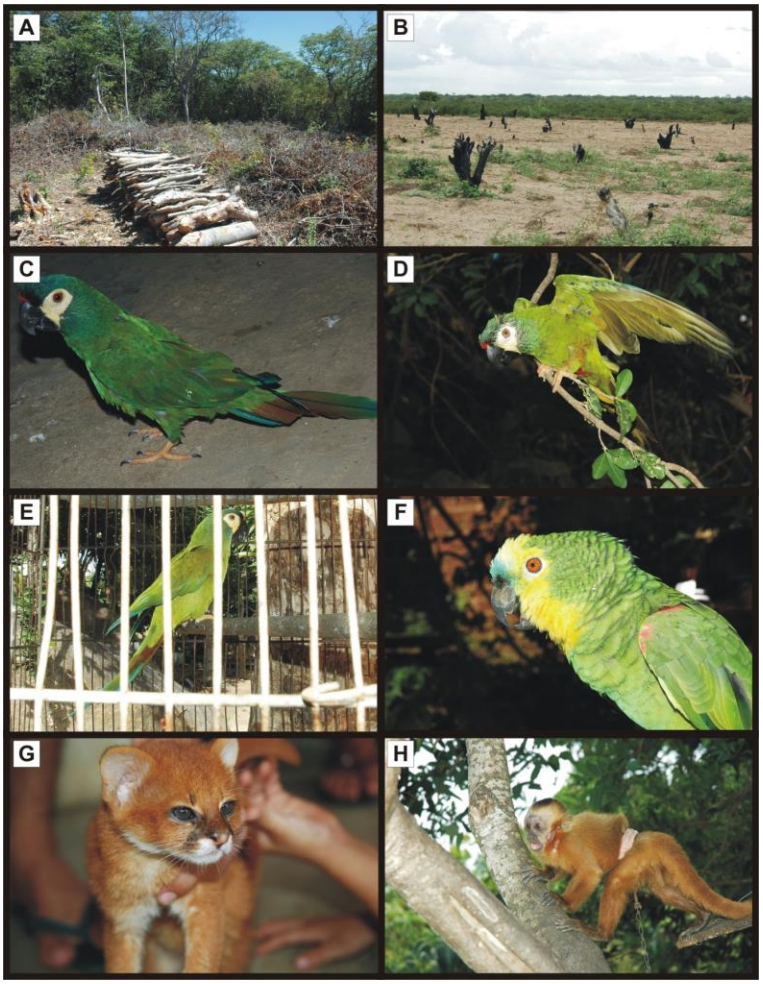

Fig. 5. Recent vegetation cutting and fauna in captivity recorded in the Serra de Santana, northeast Brazil. A and B: slash-and-burn activity and vegetation clearing observed in 2009; C, D and E individuals of Blue-winged Macaw (*Primolius maracana*) observed in captivity (in the respective sites 1 on 16 October 2009, 53 on 26 June 2010 and 53 on 3 August 2010); F: Turquoise-fronted Amazon (*Amazona aestiva*) observed in captivity in the site 53 on 26 June 2010; G and H: a Jaguarundi cub (*Puma yagouaroundi*) and a Black-striped Capuchin (*Cebus libidinosus*) observed in captivity in the site 1 on 27-28 February 2010.

Implications for conservation

In the Seridó region, *P. maracana* is restricted to just a few known sites, indicating a significant population decline in the last 30 years. In the most heavily impacted areas, where plant cover has been seriously reduced, particularly in highland plateaus and degraded hillsides, the species is absent. This corroborates what is already known about the species' habitat selection in southeastern Brazil, where plant cover has been shown to be the best predictor variable for the occurrence of *P. maracana*, and more specifically that a mosaic of small fragments is unable to sustain the species [22, 23].

The effective conservation of priority areas for *P. maracana* in this study will only be possible through the creation of legally protected areas and adequate law enforcement. The most effective means of conserving

species is usually to protect large tracts of pristine habitat, which favours the majority of threatened birds [1, 33, 41]. In the current case, it will be necessary to create and implement a series of conservation units that encompass the Pimenteira-Rio Fundo and Serra da Arara-Serra de São João polygons (A and B in Fig. 2). We recommend that a conservation unit with total protection be created for the geographic area represented by each polygon, including a margin of at least 2.5 km around each area in order to preserve the surrounding caatinga and the flat portion of the highland area. An Environmentally Protected Area (APA - following the Brazilian system of protected areas) should also be established between these units to include the fragments of caatinga vegetation on the flat elevated portion of the highlands and adjacent hillsides, to create an ecological corridor between the aforementioned protection units.

As a complementary action for maintaining existing habitat and preventing additional loss, it will be important for the federal government to provide better incentives for private landowners to establish Private Natural Heritage Reserves (RPPN - following the Brazilian system of protected areas) throughout the Serra de Santana. This voluntary conservation mechanism already exists in Brazil, but it must be facilitated by greater fiscal incentives and/or publicly subsidized technical assistance to landowners, otherwise it will never be pursued to any great effect. It is also important to recognize that the entire Serra de Santana region can potentially be considered an Important Bird Area (IBA) by criteria A1 (globally threatened species) and A2 (restrict-range species), according to Wege and Goerck [41] and Bencke and Maurício [42].

Measures that encourage local development projects and socio-economic improvements to improve quality of life and foster respect for regional culture and natural resources must also be implemented. A concrete local possibility lies in the promotion of tourism, especially ecological and rural attractions. Ecotourism has the potential to give demonstrable economic value to large, colorful parrots and macaws, and contribute a sustainable source of revenue to the local economy [3]. Promoting environmental awareness and encouraging responsible environmental practices should become a top priority among the communities in this region if we are to change and improve the way in which the limited resources of the Serra de Santana are used. We suggest that the first step in this direction is to support environmental education programs and provide technical assistance to the communities and private properties located in or around priority areas. The initial goal should be to raise awareness among the population, to denounce the continued capture, hunting and sale of wildlife as a criminal activity, and to minimize the further loss of native vegetation and encourage the responsible use of soil and other resources.

Finally, it must be stated that we believe *P. maracana* already has a low potential for recovery in caatinga environments due to its intrinsic life history traits, characteristic of a K-strategist (long lifespan, relatively late sexual maturity, low percentage of pairs breeding, monogamy, highly social group behaviors, and selectivity of tree cavity-nesting sites). The conservation situation here is compounded by an array of extrinsic variables, including fragmented and highly restricted habitat that suffers from ongoing impacts of human activity, possibly worsening drought conditions related to climate change, and the uncontrolled illicit capture of wild birds for the illegal pet trade. The measures proposed here must be enforced as soon as possible to ensure any chance of conserving *P. maracana* at the northeast limits of its distribution. Our work will contribute to knowledge of the current distribution, population status, and ongoing threats to *P. maracana*, actions considered necessary for this species in the IUCN Parrot Conservation Action Plan [3].

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Appendix 1. Sites sampled between October 2009 and October 2010 in Serra de Santana, Northeast Brazil for searching of Blue-winged Macaw (*Primolius maracana*). The sites are identified with reference number, location name, coordinates, altitude and are grouped by municipalities.
Municipality of Santana do Matos: 1-Sítio Pimenteira (06º04'10.4"S-36º39'05.5"W, 614 m); 2-Serra do Cajueiro (06º03'08.8"S-36º46'13.7"W, 615 m); 3-Belvedere of the Serra do Cajueiro (06º01'43.1"S-36º47'04.7"W 634 m); 4-North Face of the Cabeço Verde, Sítio Pimenteira (06º03'33.8"S-36º44'39.2"W, 714 m); 5-South Face of the Cabeço Verde, Sítio Pimenteira (06º03'48.9"S-36º44'56.9"W, 655 m); 6-Serra Nova I (06º03'32.7"S-36º45'13.4"W, 686 m); 7-Riacho dos Mulungus (06º03'24.6"S-36º39'03.1"W, 558 m); 8-Cabeço Verde (06º04'27.4"S-36º39'35.5"W, 670 m); 9-Chã da Curicaca settlement (06°04'41.2"S-36°43'02.9"W, 690 m); 10-Serra Nova settlement (06°06'40.5"S-36°44'17.7"W, 686 m); 11-Serra Nova II (06°03'41.3"S-36°45'17.0"W, 709 m); 12-Cachoeira do Nego (06°03'57,3"S-36°38'32.1"W, 410 m); 13-Serra Nova III (06°02"48.0"S-36°43'48"W, 694 m); 14-Cícero Anselmo I settlement (06°04'42.7"S-36°36'58.6"W, 674 m); 15-Arisco (06°05"04.4"S-36°38'59,3"W, 614 m); 16-Sítio Guedes - Chapel (06°04'53.4"S-36°38'04,3"W, 662 m); 17-Serra Rajada (06°03'37.2"S-36°38'00.4"W, 517m); 18-Cícero Anselmo II settlement (06°04'10.2"S-36°36'20.6"W, 617 m); 19-Avelinos farm (06°03'38.0"S-36°36'14.5"W, 649 m); 20-Cabeço do Ferreira I (06°03'03,2"S-36°34'37.1"W, 691 m); 21-Paraíso Açu II (06°00'44.4"S-36°30'17.0"W, 618 m); 22-Cachoeira do Perigo (06°03'21.3"S-36°41'18,4"W, 448 m); 23-Rio Fundo (06°03'02.2"S-36°41'18.6"W, 629 m); 24-Curicaca (06°05'12.4"S-36°42'31.8"W, 639 m); 25-Chã Preta I (06°02'25.9"S-36°42'20.8"W, 669 m); 26-Chã Preta II (06°02'58.0"S-36°43'02.1"W, 648 m); 27-north edge of the Serra de Santana (06°03'07.4"S-36°35'38.8"W, 660 m); 28-Serra Nova IV (06°03'08.2"S-36°33'30.1, 711 m); 29-Cabeço Ferreira II (06°02'06.2"S-36°33'39.2"W, 668 m); 30-Rio da Salsa (06°01'05.2"S-36°40'18.5"W, 145 m); 31-Sítio Chico Ferreira (05°58'16.6"S-36°39'24.2"W, 145 m). Municipality of Tenente Laurentino Cruz: 33- west edge of the Serra de Santana (06º09'32.2"S-36º44'00.5"W, 740 m); 34-Sítio Jarauto I (06º10'46.6"S-36º43'21.1"W, 754 m), 35-Mata da Lanchinha (06º06'57.5"S-36º41'22.2"W, 681 m); 36-Tanquis Preto (06º05'36.4"S-36º43'26.0"W, 680 m), 37-Sítio Jarauto II (06º08'16.1"S-36º43'29.8"W, 700 m). Municipality of São Vicente: 38-Serra Piauí (06º08'23.5"S-36º39'07.0"W, 700 m). Municipality of Currais Novos: 39-Serra da Ripina (06º08'59.0"S-36º37'16.4"W, 729 m). Municipality of Lagoa Nova: 40-Sítio Serrinha (06º06'58.6"S-36º25'21.4"W, 650 m); 41-Lagoa Nova I (06°04'07.5"S-36°32'34.9"W, 689 m); 42-Lagoa Nova II (06°06'43.2"S-36°27'53.7"W, 691 m); 43-Lagoa (06°06'06.4"S-36°28'10.0"W, 678 m). Municipality of Bodó: 44-Adutora (06°00'31.0"S-36°24'40.9"W, 707 m); 45-Sítio José Ferreira (05°59'32.3"S-36°25'46.8"W, 653 m). Municipality of Cerro Corá: 46-Marco do Cinquentenário (06°05'49.4"S-36°20'37.8"W, 689 m); 47-Cerro Corá-plateau (06°04'57.2"S-36°21'40.4"W, 705 m); 48-Serra de São João I (06°02'17.4"S-36°17'29.6"W, 363 m); 49-Serra da Arara-Sítio Bala I (06°04'46.4"S-36°18'22.8"W, 398 m); 50-Sítio Pinga (06°01'54.2"S-36°17'07.2"W, 342 m); 51-Pamonha (06°04'50.2"S-36°17'11.4"W, 407 m); 52-Arara water reservoir (06°05'06.8"S-36°19'31.3"W, 464 m); 53-Cerro Corá city (06°02'37.2"S-36°20'48.7"W, 554 m); 54-Cerro Corá-hillsides (06°00'56,6"S-36°18'42,3"W, 388 m). Municipality of Lajes Pintadas: 55-Serra Verde (06°06'59.4"S-36°12'37.6"W, 661 m). Municipality of São Tomé: 56-Serra Boa Ventura (06°06'11.82"S-36°15'19.6"W, 235 m).