Bird Conservation International (2019) 29:400–412. © BirdLife International, 2018
doi:10.1017/S0959270918000321

Combining local knowledge and field surveys to determine status and threats to Timneh Parrots *Psittacus timneh* in Guinea-Bissau

DANIEL C. LOPES, ROWAN O. MARTIN, MOHAMED HENRIQUES, HAMILTON MONTEIRO, PAULO CARDOSO, QUINTINO TCHANTCHALAM, ANTÓNIO J. PIRES, AISSA REGALLA and PAULO CATRY

Summary

Timneh Parrots *Psittacus timneh* are a threatened species endemic to the moist forests of West Africa. In 2016, they were categorised as 'Endangered' on the IUCN Red List, due to suspected rapid population declines driven by habitat loss and heavy trapping for the pet trade. Systematic assessments of the status of populations are lacking for much of their range and addressing this knowledge shortfall has been identified as a priority action. We combined multiple research approaches to investigate the distribution, trends and threats to Timneh Parrots in Guinea Bissau, where the species is restricted to the islands of the Bijagós archipelago and Pecixe. Direct observational surveys were conducted along line transects on 19 islands. A total of 69 groups were observed on eight of these islands, with the majority (78%) seen on just two islands. Forty-two interviews were conducted with local community members on 24 islands. Interviewees reported the species to occur on 20 islands and that populations are generally perceived to have declined in recent decades. Based on these findings and existing data we conclude that Timneh Parrots occur on 22 of the 32 islands considered and estimate the national population in Guinea-Bissau to be in the order of several hundred individuals, with perhaps half of the parrots occurring on the islands of João Vieira and Meio. Investigations into the factors linked to inter-island variation in parrot densities indicate that densities are highest on the islands which are most remote from permanent human settlements. These findings suggest that human activities including habitat modification and trapping have been important in driving population declines in Guinea-Bissau. We consider the implications of these findings for the conservation of Timneh Parrots.

Introduction

Parrots (Psittaciformes) are one of the most threatened groups of birds, with 28% of 398 parrot species listed as threatened in the IUCN Red List of Threatened Species (BirdLife International 2017a, Heinsohn *et al.* 2018). In Africa, six species are considered threatened or 'Near Threatened', with the most commonly cited threats being hunting and trapping and habitat loss (Olah *et al.* 2016). Among the species considered most threatened are Timneh Parrots *Psittacus timneh*, which were recognised as distinct from Grey Parrots *Psittacus erithacus* in 2012 (Collar 2013) and uplisted to 'Endangered' in 2016 (BirdLife International 2017b).

Timneh Parrots are restricted to areas of moist forest in West Africa, and have a fragmented distribution stretching from western Côte d'Ivoire through Liberia, Sierra Leone, Guinea and Guinea-Bissau (Perrin 2012, del Hoyo *et al.* 2018). Forests in this region have suffered dramatic declines, due to agricultural expansion, infrastructure development and logging. Some estimates

suggest that the Guinean forests currently occupy only 15% of their original extent (Mittermeier *et al.* 2004) and a recent study found that forests in West Africa suffered a loss of 83.3% between 1900 and 2000 (Aleman *et al.* 2017).

In addition to habitat changes, large numbers of Timneh Parrot have been trapped for the global pet trade. *Psittacus* parrots (*P. timneh* and *P. erithacus*) are highly popular as pets and have been among the most traded of all birds listed on the Appendices of CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) (Martin 2018a). Between 1975 and 2014, net exports of 1.22 million wild-sourced *Psittacus* parrots were reported in international trade by CITES Parties and many of these were exported from countries in West Africa, with at least 176,000 specified as being *Psittacus e. timneh* (Martin 2018b). The true number of Timneh Parrots taken from the wild is likely to be considerably greater as many CITES parties did not report trade to subspecies level, reporting only the nominal species *P. erithacus* (Martin *et al.* 2014, Martin 2018b). Furthermore, many likely died prior to export (Fotso 1998a, 1998b, McGowan 2001), were illegally trafficked (Dändliker 1992, Clemmons 2003) or have been traded domestically (i.e. did not cross international borders; R. Martin pers. obs.).

The combined impacts of overexploitation and forest loss are thought to have led to the decline of populations of *Psittacus erithacus* populations in Ghana by 90–99% since the 1990s (Annorbah *et al.* 2016). Given the similarities in the threats affecting Timneh Parrots in neighbouring countries, this collapse has served to highlight the potentially precarious conservation status for the species and the need for greater conservation attention. Systematic assessments of the status of populations are lacking for most range states and the identification of key sites for conservation has been highlighted as a priority action (Martin *et al.* 2014, BirdLife International 2017b).

In this study, we focus on understanding the status and threats to Timneh Parrots in Guinea-Bissau. There are reports of Timneh Parrots in Guinea-Bissau going back to the 16th century (Almada 1964), and in 1961 a faunal survey of the region reported the occurrence of Timneh Parrots on offshore islands, including the Bijagós archipelago (Naurois 1981). More recent surveys (Limoges and Robillard 1991, Rodwell 1996, Campos *et al.* 2001, Clemmons 2003, Dodman *et al.* 2004) and subsequent inquiries suggest that Timneh Parrots are absent from the mainland and restricted to small populations on selected islands. Although the trapping of Timneh Parrots has been prohibited in Guinea-Bissau since 1980, this practice has continued, and forest clearance for agriculture occurs on several islands (Catry 2013, Henriques and Lopes 2014).

We conducted the most comprehensive survey of Timneh Parrots to date, combining field surveys with interviews with members of the local communities, to establish the species' current distribution, indices of abundance and population trends within the Bijagós islands. We further examined the factors linked to the occurrence of Timneh Parrots across islands in the archipelago to understand which processes determine their current distribution.

Methods

Study site

The study focused on a group of islands off the coast of Guinea-Bissau, the majority of which comprise the Bijagós archipelago (approximately 88 islands and islets), together with the nearby islands of Pecixe and Jeta (Figure 1). The area has a tropical climate, with two distinct seasons: a dry season (from mid-November to mid-May) and a rainy season (from mid-May to mid-November). The mean annual temperature is 26.1° C and the mean annual rainfall is 2,000 mm. Apart from shallow marine waters, the environment is dominated by intertidal habitats with vast areas of mangrove, and terrestrial forest representing a relatively small fraction of the area covered by the islands (Table 1). Other habitats include grasslands and savannahs (Cuq 2013). Classified as a Biosphere Reserve by UNESCO in 1996, this archipelago includes three protected areas: Orango National Park (ONP), Communitarian Marine Protected Area of the Urok Islands (CMPAUI) and João Vieira-Poilão Marine National Park (JVPMNP).

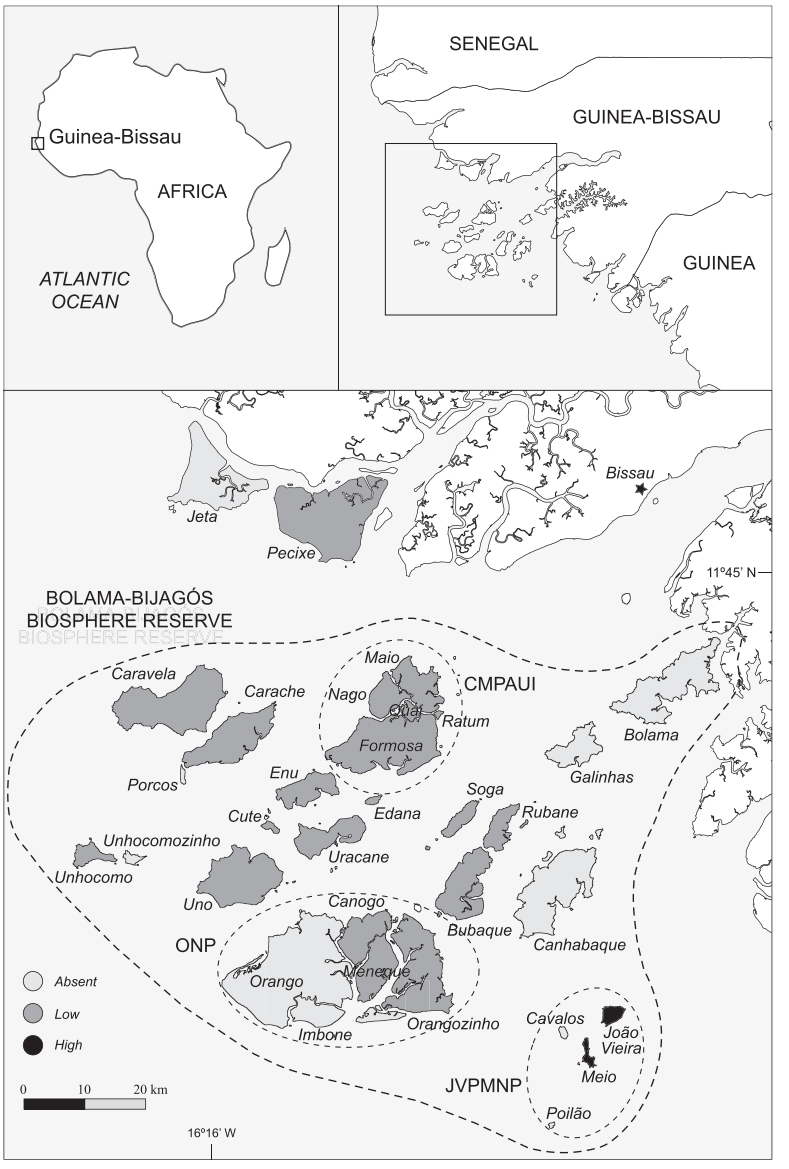

Figure 1. Map of the study area, showing the protected areas of the Bijagós archipelago (ONP - Orango National Park, CMPAUI - Communitarian Marine Protected Area of the Urok Islands, JVPMNP - João Viera and Poilão Marine National Park), the location of the islands included in this study, and the distribution and abundance of Timneh Parrots.

Island surveys: interviews and line transects

We combined multiple methodological approaches to determine the status of Timneh Parrots throughout the study area. Due to logistical constraints, it was not possible to visit all islands and so surveys were targeted on 27 of the larger islands, selected due to their size, the presence of suitable habitat, and existing knowledge on the status of parrot populations. We visited all islands with an area greater than 1.8 km², which included all islands with permanent human settlements as well as

https://doi.org/10.1017/S0959270918000321 Published online by Cambridge University Press

Table 1. Summary of characteristics of islands, survey effort, and indicators of parrot density for the islands of the Bijagós archipelago and Pecixe surveyed in this study.

Island	Island Area (km²)	Human Density (hab/km²)	Forest cover (km²)	Protected Area? (since the year)	Distance covered during transects (km)	Encounter Rate (groups hr⁻¹)	Max. Group Size Observed	Density Category
Bijagós archipelago	1,040	31.18	400 (38.46%)	Yes (1996)	-	-	-	-
Bolama	65.91	100.16	13.57 (20.59%)	No	-	-	-	absent
Bubaque	43.39	148	22.9 (52.03%)	No	12.18	0.5	1	low
Cannhabaque	91.14	27.19	49.31 (53.11%)	No	-	-	-	absent
Canogo	20.26	2.61	12.35 (60.79%)	Yes (2000)	5.42	0	-	low
Carache	40.53	10.56	24.37 (54.86%)	No	4.85	0.47	1	low
Caravela	74	7.77	63.29 (50.69%)	No	7.4	0	-	low
Cavalos	2.1	0	1.26 (61.89%)	Yes (2000)	-	-	-	absent
Cute	2.3	0	2.22 (91.41%)	No	1.25	1.33	1	low
Edana	1.8	0	0.88 (46.26%)	No	1.4	0	-	low
Enu	15.72	0	5.2 (28.43%)	No	5	0	-	low
Formosa	94.42	19.83	56.01 (59.32%)	Yes (2005)	-	-	-	low
Galinhas	24.16	67.59	12.12 (46.50%)	No	-	-	-	absent
Imbone	18.6	1.4	0.71 (3.27%)	Yes (2000)	4.3	0	-	absent
Jeta	-	-	-	No	-	-	-	absent
João Vieira	9	0.67	5.61 (62.6%)	Yes (2000)	12.31	6.73	42	high
Maio	18.73	23.28	14.65 (70.03%)	Yes (2005)	-	-	-	low
Meio	4.02	0	1.41 (33.54%)	Yes (2000)	5	2.1	22	high
Meneque	18.8	6.49	3 (14.59%)	Yes (2000)	-	-	-	low
Nago	21.11	29.32	14.12 (62.04%)	Yes (2005)	-	-	-	low
Orango Grande	158.82	7.71	28.48 (16.57%)	Yes (2000)	20.63	0	-	low
Orangozinho	45.66	15.46	3.39 (6.72%)	Yes (2000)	13.86	0.21	7	low
Pecixe	91.14	-	-	No	12.33	0.98	8	low
Poilão	1.85	0	0.27 (55.07%)	Yes (2000)	-	-	-	absent
Porcos	1.11	0	0.11 (10.81%)	No	-	-	-	absent
Quai	1.85	0	1.57 (74.3%)	Yes (2005)	-	-	-	low
Ratum	1	0	0.07 (15.84%)	Yes (2005)	-	-	-	low
Rubane	17.05	9.68	12.97 (62.74%)	No	4.35	0	-	low
Soga	12.9	62.27	9.06 (69.34%)	No	2.75	0	-	low
Unhocomo	14.32	37.35	3.51 (23.19%)	No	6.2	0.6	2	low
Unhocomozinho	3.77	42.44	0.35 (8.86%)	No	2.85	0	-	absent
Uno	82.57	40.26	16.7 (19.19%)	No	6.5	0	-	low
Uracane	18.6	63.49	17.45 (62.44%)	No	4	0	-	low

all islands that occur within the three protected areas. Exceptions were made for five islands for which existing knowledge, based on previous surveys, enquiries with parrot trappers and recent visits by ornithologists, indicated that Timneh Parrots are absent, suggesting further surveys at this time were unnecessary. These include the four inhabited islands of Bolama, Canhabaque, Galinhas and Jeta, and the uninhabited island of Porcos. A total of 32 islands are thus included in this study.

Surveys were conducted between 2013 and 2015, with a subset of the islands visited in each year (Table 1). Interviews were conducted on 24 islands with members of the local communities. Given that baseline data are lacking for most islands, and that the survey team was only able to visit each island for a relatively short period, surveying local knowledge to leverage "community wisdom" can provide valuable insight into population processes and conservation problems (Surowiecki 2005, Predavec *et al.* 2016). Interviewees were initially selected based on recommendations by community leaders and selection subsequently followed a snowball sampling approach (Goodman 1961) to identify additional

https://doi.org/10.1017/S0959270918000321 Published online by Cambridge University Press

participants likely to have knowledge relevant to the study's aims. In total, 69 interviews were conducted involving 207 people; participants were interviewed together in groups in some instances. Although data collected from local knowledge can be comparable to those collected using conventional methods (Danielson *et al.* 2005, Jones *et al.* 2008, Parry and Peres 2015), the characteristics of observers such as age (Turvey *et al.* 2010) and experience (Cerqueira *et al.* 2013) can influence ability to detect a species accurately. The sampling approach meant that all participants were men, as they were considered to have greater direct experience of parrot behaviour and ecology, since within local culture they typically spend a much greater proportion of their time engaged in activities in forested areas, and traditionally only men trap parrots. The semi-structured interviews covered a wide range of topics, including aspects of parrot ecology relevant to investigations conducted in parallel. Specific questions aimed at establishing local knowledge on the status of populations included: i) have you seen Timneh Parrots on this island in the last year? and ii) what is the largest group you have seen? Interviews were conducted in Creole and translated to English by PC and MH.

Between March and June in 2014 and 2015, at the same time that islands were visited to conduct interviews, observational field surveys were also conducted along line transects (Sutherland *et al.* 2004) Forty-two transects were surveyed covering a total of 132.6 km across 19 islands. The distance surveyed on each island varied between 2.9 and 20.6 km, depending on the size of the island and accessibility. Transects were located along existing trails, since it was not feasible to position transects at random within the landscape, due to the difficulties accessing many areas of each island. All surveys were conducted between 06h30 and 09h30, with each transect surveyed only once. Two observers walked together on each transect at approximately 2 km h^{-1}. The duration of each transect was recorded and every time an individual or group of Timneh Parrots was observed, records were made of the number of individuals and the perpendicular distance of the group from the trail. In addition, their behaviour (perched, flying or feeding) was noted. During this period, the islands of Poilão and Cavalos were also visited by some of the authors and are included in this study, although no interviews nor transects were conducted; these islands are uninhabited, very small (1.8 and 2.1 km^2, respectively) and were searched non-systematically for parrots.

On the islands of João Vieira and Meio, which were the focus of additional research and conservation efforts due to their relatively high parrot population densities and status as protected areas (Lopes *et al.* 2018a), we additionally conducted counts of Timneh Parrots along flyways (Sutherland *et al.* 2004). The location of these points was chosen based on previous knowledge on the flight paths used every day by Timneh Parrots to move between nesting and feeding areas (Amuno *et al.* 2007, Lopes *et al.* 2018b). We established two points on João Vieira (JV1 and JV2), located in an open savannah habitat, with very good visibility in all directions (coordinates UTM 28 N: 0431310/1221740 and 0429853/1219793). On Meio, we established three points (M1, M2 and M3), with two located on beaches in opposite sides of the island and one in an open area in the centre of the island similar to the points used on João Vieira (coordinates UTM 28 N: 0426868/1213486, 0426499/1213744 and 0427305/1213540). An initial full day count suggested that parrots are most active along these flyways during the early morning and late afternoon. These points were then monitored from 06h00 to 09h30, and from 16h30 to 19h30, during which each flying parrot observation was recorded. We conducted a total of 48 counts between March and June 2014, 25 on João Vieira and 23 on Meio. These counts were intended to be part of a repeatable methodology for the local monitoring of Timneh Parrot populations and were additionally used to support the estimates of population size.

Estimates of abundance and trends

Distance sampling along line transects is one of the most common methods for estimating abundance and densities of parrot populations (Marsden and Royle 2015, Dénes *et al.* 2018). However, this method can only be effectively applied when densities are relatively high (Marsden *et al.* 2015). The low densities found within the study area resulted in only 22 encounters of perched parrots despite considerable survey effort. This is substantially lower than the recommended minimum of around 80 encounters required to generate reliable detection functions (Buckland *et al.* 2007).

https://doi.org/10.1017/S0959270918000321 Published online by Cambridge University Press

It has been suggested that basic encounter rates (number of birds encountered per hour) can be used in situations where parrots are too rare to be surveyed effectively using distance sampling, to indicate local abundance (Marsden *et al.* 2015). Given that estimates of population size are often solicited by decision-makers and feed into processes such as the IUCN Red List (IUCN 2012), we report basic encounter rates and use these in combination with information from additional sources, including flyway counts on the islands of João Vieira and Meio, to propose an initial coarse estimate of the number of parrots in Guinea-Bissau.

A semi-quantitative assessment of recent population trends was inferred from the responses received during interviews with local community members. Interviewees were asked if they see more or fewer parrots than in the past and since when have they seen a change in numbers. A total of 41 responses were received and their answers aggregated to determine the proportion of respondents who reported positive, negative or no change in numbers over specific time periods spanning 10–30 years.

Drivers of parrot density between islands

To explore the factors which drive variation in the density of parrots between islands, we examined the relationship between several island characteristics, hypothesised to be linked to parrot density, and an ordinal index of parrot density based on the synthesis of information from multiple sources. We established three categories of abundance which were considered as an ordinal response variable: islands on which enquiries and direct observations suggest that parrots are not present were categorised as 'absent', islands on which parrots are known to be present but encounter rates were between 0 and 1.5 groups hr^{-1} were considered as having 'low' density and islands with encounter rates >1.5 groups hr^{-1} and up to 6.7 were considered 'high' density islands. In total, information was available for 32 islands.

We built a statistical model to examine the relationship between three variables, fitted as fixed effects in our model. Following the results of the enquiries, and based on assessments of threats to closely related parrot species (BirdLife International 2017b, Annorbah *et al.* 2016), we hypothesised that the availability of suitable habitat and the risk of exploitation for the pet trade would be likely determinants of parrot distribution among the islands. We used total forest area as a proxy measure of habitat availability and obtained this from a supervised classification of a multitemporal scheme of satellite imagery classification. We used two cloud-free Landsat 8 images (Scenes LC82040522014318LGN00 from 2014-11-14 and LC82040522015081LGN00 from 2015-03-22) to extract Tasseled Cap (Huang *et al.* 2002) synthetic bands (Greenness, Brightness and Wetness) and vegetation index ratio (NDVI) from Landsat OLI bands 2-7. We trained a Random Forest classifier (Breiman 2001) with 500 trees and four main Land cover types (Forests, Water, Mangroves and Other terrestrial habitats). We split a ground truthing sample obtained in 2014 into training (75%) and test (25%) subsets to obtain an overall accuracy above 98% for the test set. The resulting classification map was relabelled to a binary Forests/Non-forest map. Total forest cover was obtained for each island. Classification procedure was performed with R software (R Core Team 2015) with 'raster' (Hijmans 2015) and 'caret' (Kuhn 2015) packages.

We used the distance to the nearest island with permanent human settlements as a proxy measure of exploitation pressure, under the assumption that the costs of travel reduce the incentive to exploit more remote populations. Traditionally, communities have relied on non-motorised boats to move between islands and the strong tidal flows make long crossings highly risky. Distances ranged between 0 km (island inhabited by people) to 32.5 km. Following observations of movements of parrots between islands (P. Catry pers. obs.), we further hypothesised that the population of Timneh Parrots may effectively function as a metapopulation and that the proximity of each island to the nearest island inhabited by parrots may also be an important determinant of density. The small sample size ($n = 32$ islands) precluded the inclusion of additional explanatory variables or the examination of any interaction effects between these three fixed effects.

These data were fitted using a Bayesian generalised linear model with an ordinal error structure using the R package 'mcmcglmm' (Hadfield 2010). An uninformative prior was used with $V = 1$ and residual variance fixed at 1. The number of model iterations was 650,000 with a burn-in

https://doi.org/10.1017/S0959270918000321 Published online by Cambridge University Press

of 100,000. Autocorrelation and convergence were checked visually and we report parameter estimates and 95% confidence intervals.

Results

Parrot distribution and abundance

Of the 24 islands surveyed through interviews with members of local communities, Timneh Parrots were reported by island residents to be recently present on 20 islands: 19 in the Bijagós archipelago and the nearby island of Pecixe (Figure 1). The accounts of local communities indicated that Timneh Parrots occurred in very low numbers on the majority of islands, with groups encountered infrequently and typically numbering between three and 10 individuals, occasionally reaching 30 individuals.

Of the 19 islands on which transect surveys were conducted as part of this study, parrots were observed directly on eight. On these islands, a total of 69 groups were encountered, comprising 225 individuals, in groups ranging between 1 and 30 individuals. Of these, 22 groups were recorded perching or feeding and 47 flying.

When combining the information produced by the different survey methods and the experience of the authors on the islands of Poilão e Cavalos, with the information on five further islands that already existed prior to this study, Timneh Parrots are known to be present on 22 of 32 islands, corresponding to 70% of the larger (area > 1.8 km^2) Bijagós islands and Pecixe.

The majority of parrots (78% of groups and 84% of individuals) were observed on the two uninhabited islands of João Vieira and Meio, both within the JVPMNP. Mean encounter rates on these islands were 5.41 groups hr^{-1}. In contrast, mean encounter rates on the other 15 islands were relatively low at 0.23 groups hr^{-1}. Group sizes differed in a similar manner, with the maximum group sizes encountered on João Vieira and Meio containing 30 and 13 individuals respectively, while the largest group seen on all other islands was eight (Table 1). The distribution of Timneh Parrots within the Bijagós islands is presented in Figure 1. Parrots were considered absent from 10 islands. Twenty islands were categorised as having a low density and two as having high density

On João Vieira, 25 flyway counts were made at the two count points, during which a total of 1,661 observations of parrots were made. On Meio, 23 counts were conducted at the three count points during which 582 observations were made. The maximum number of observations recorded for João Vieira on a single 3.5-hour count was 261 at one point and 78 at the other. For Meio, the maximum number of observations recorded in one count was 120. Means of the number of observations recorded for each point are presented together with standard deviations in Table 2. Groups observed on flyways were generally small - groups of only two individuals accounted for more than 50% of the observations and groups of 1–3 individuals accounted for more than 80% of the

Table 2. Results of flyway counts conducted at five sites on the islands of João Vieira (JV) and Meio (M) during two periods of the day (morning and afternoon); *n* - number of survey periods; Total observations - total number of parrots recorded, Mean ± SD – mean number of observations per period (± SD). Note that counts covered the hours of parrot feeding activity with movements in opposing directions (possibly moving from and to feeding sites), and therefore almost certainly include repeated observations of the same individuals, hence numbers recorded overestimate the true number of individuals observed.

	n	Total observations	Mean ± SD
JV1-Morning	6	627	104.50 ± 86.23
JV1-Afternoon	6	418	69.67 ± 42.29
JV2-Morning	6	288	48.00 ± 18.20
JV2-Afternoon	7	328	46.86 ± 17.53
M1-Morning	8	410	51.25 ± 36.22
M1-Afternoon	1	16	-
M2-Morning	7	118	16.86 ± 11.14
M3-Morning	7	40	5.71 ± 3.04

https://doi.org/10.1017/S0959270918000321 Published online by Cambridge University Press

observations. Larger groups were occasionally observed – on João Vieira the maximum recorded group size was 42, and on Meio the largest group had 22 individuals.

Trends in populations

Of the 42 interviews conducted with members of local communities on 19 islands during 2014 and 2015, 33 (79%) interviews from 17 (89%) islands reported that Timneh Parrot populations have declined over the last 30 years. One interviewed group claimed not to have sufficient experience to evaluate trends. On one island (Soga), locals reported that parrots occurred in similar numbers as in the past, and on another island (Cute), locals mentioned a recent increase in parrot numbers, but did not compare the current situation with a more distant past. Recent increases in parrot populations were mentioned in 18 (43%) interviews from 10 islands, but no detailed information on the exact timing of the increase could be obtained. During surveys conducted in 2013 on three additional islands (Formosa, Chediã and Nago), long-term population declines were reported on all three. No interviews were made on uninhabited Poilão, however the experience of researchers (Paulo Catry pers. obs., Castro Barbosa pers. comm.) that have visited the island regularly over the last 20 years indicates an apparent decline, with no observations recorded in recent years.

Factors associated with distribution and abundance

Parameter estimates and 95% credibility intervals for the three explanatory variables included in our model are presented in Table 3. Of the three variables, distance from permanent human settlement was found to be marginally positively associated with parrot abundance whereas distance from the nearest island with a parrot population was negatively associated with abundance. There was no indication that the total area of forest cover was associated with the abundance of Timneh Parrots, with 95% confidence intervals overlapping with zero.

Discussion

Our study found that although Timneh Parrots are widely distributed among the islands of the Bijagós archipelago and Pecixe, densities were generally low and perceived by members of the local communities to have declined in recent decades. There was considerable variation among islands, and while parrots were absent or at very low densities on some of the larger islands, there were notably higher densities on some smaller, remote and uninhabited islands.

The drivers of the observed variation in density among islands are likely complex and involve a number of factors acting in concert. The islands with the highest densities (João Vieira and Meio) are notable in that they are among a group of small islands on the edge of the archipelago and among the most inaccessible from the Guinea-Bissau mainland. Our analysis suggests that remoteness from permanent human settlements may be linked to local densities. The islands of João Vieira and Meio are owned by communities on the nearest island of Canhabaque through a traditional tenure system which has restricted the activities that take place on them. These restrictions mean that no permanent villages have been established on the islands, and although groups of villagers visit the islands for extended periods to practice shifting agriculture and harvest forest products, the extent of these activities is limited. Since 2000, these islands have been managed by the national institution for protected areas (IBAP) in collaboration with local communities, and form

Table 3. Outputs of an ordinal response model examining the association of three variables hypothesised to be linked with variation in the density of parrots among islands.

	Parameter estimate	l 95% CI	u 95% CI
Forest cover	0.0087	-0.020	0.038
Dist. from permanent human settlement	0.11	0.0013	0.21
Dist. from nearest parrot population	-0.36	-0.69	-0.091

https://doi.org/10.1017/S0959270918000321 Published online by Cambridge University Press

part of the João Vieira-Poilão Marine National Park. These islands also support globally important turtle nesting areas (Catry *et al.* 2009) and it is possible that their remoteness in combination with traditional protection may have played an important role in shielding Timneh Parrots as well as nesting turtles from levels of exploitation occurring in other areas.

The proximate factors that might link distance to human settlements with parrot densities are unclear but Timneh Parrots have been trapped as adults as well as harvested from nests as chicks to supply the pet trade, and this practice has likely taken place at unsustainable levels. Discussions during interviews revealed that trapping has been widespread among the islands and that once harvested, Timneh Parrots are taken to Bissau, where they likely enter the international market. Although Guinea-Bissau has reported only very few exports of Timneh Parrots (www.trade.cites.org: UNEP WCMC, Cambridge UK, downloaded 14th March 2018), the neighbouring countries of Senegal and Guinea have exported very large numbers and have at times been among the largest exporters of *Psittacus* parrots (Martin 2018b). Given the slow life-history of this species, the trapping of adults can be particularly detrimental to populations (Valle *et al.* 2018). The recent transfer of Timneh Parrots to Appendix I of CITES, prohibiting international trade in wild-sourced specimens and requiring the verification of captive-breeding facilities aims to reduce demand for wild parrots and may help reduce the pressure from international markets on local populations in Guinea-Bissau.

Timneh Parrots are secondary cavity nesters and are reliant on the natural generation of large cavities, which tend to occur in larger and more mature trees (Lopes *et al.* 2018a). An investigation of the distribution of Timneh Parrots nest cavities on the islands of João Vieira and Meio, conducted in parallel to this study, found that nests occur disproportionately in the largest trees and also tend to be clumped in distribution (Lopes *et al.* 2018). Large trees are used for the construction of canoes, which are used for transport around the islands and for fishing. A scarcity of large trees due to selective felling or abiotic factors such as soil type may explain why Timneh Parrots are scarce or absent on islands that have considerable areas of forest cover. An ongoing study examining whether Timneh Parrots will occupy artificial nest cavities when available will inform the potential for using this approach to address potential nest site limitation.

It is further possible that the conversion of forest for agriculture may also reduce food availability. Timneh Parrots have been recorded feeding on a wide diversity of almost 40 plant species and a range of plant parts including fruits, seeds and even sap (Lopes *et al.* 2018b). However, the extent to which Timneh Parrots rely on different food sources at different times of the year and the availability of these foods within different habitat types remains unclear.

It is also possible that some areas of mangroves provide nest cavities or other important resources in addition to terrestrial forests, which creates extra variability not captured by our modelling exercise. The potential importance of mangroves was suggested by several interviewees and an *ad hoc* visit to a site reported as containing nesting pairs revealed what appeared to be at least one active nest in mangroves. This nesting area, close to the island of Orangozinho, yet difficult to access, may explain why several groups of Timneh Parrots were seen on that island despite it having a high human population and little forest cover. Its close proximity to forested areas of the island of Canogo could also play a role.

The encounter rates recorded on most islands indicated that densities were generally very low and comparable with the lowest densities recorded for *Psittacus* parrots elsewhere in their range (Marsden *et al.* 2015). However, in contrast, the density observed on the island of João Vieira is the highest recorded to date for Timneh Parrots and comparable with the very high densities observed on the island of Príncipe for Grey Parrots (Marsden *et al.* 2015, Valle *et al.* 2017). Although estimating the population size of Timneh Parrots of Guinea-Bissau was not an aim of this study at the outset, in order to explore the relative importance of the islands of João Vieira and Meio versus the other islands of the Bijagós, we attempted to infer the population of these islands based on available data on encounter rates and flyway counts. We used the relationship between encounter rates (ER) and *Psittacus* parrot densities estimated using distance sampling reported by Marsden *et al.* (2015) to infer crude estimates of densities on the two groups of islands. The mean ER for the islands of João Vieira and Meio, was 5.41 groups hr^{-1} which corresponds to an approximate density of 59 parrots km^{-2}. The mean ER on all other islands was 0.23 groups hr^{-1},

https://doi.org/10.1017/S0959270918000321 Published online by Cambridge University Press

which corresponds to an approximate density of 0.12 parrots km^{-2}. Multiplying these values by the area of the islands, and excluding areas where parrots are confirmed absent, we estimate approximately 754 individuals on the islands of João Vieira and Meio and approximately 557 individuals on all other islands of the Bijagós archipelago and Pecixe. For João Vieira and Meio we compared this estimate with the data from flyway counts. The maximum numbers counted at each count point on João Vieira were 261 and 78 and on Meio the maximum recorded was 120 individuals. This results in a total of 459 for both islands. However, as these counts covered the hours of parrot feeding activity and we often watched movements in opposing directions (possibly moving from and to feeding sites), we almost certainly made repeated observations of the same individuals and as such these numbers overestimate the true number of individuals observed. Furthermore, we were conservative in the delimitation of areas where parrots are absent in other islands (beyond JVPMNP), and therefore when we multiply estimated densities by the (presumably) occupied area we are overestimating the population. Based on the above we tentatively propose there are at least several hundred, but probably less than a thousand Timneh Parrots in Guinea-Bissau and that at least half of the population likely occurs within the JVPMNP on the islands of João Vieira and Meio.

Local community members throughout the archipelago generally perceived that parrot populations have declined in living memory, a finding which was also suggested by previous studies (Clemmons 2003). A small number of interviewees reported there has been an increase in numbers of parrots in the last decade, raising the possibility that populations may be beginning to stabilise or even recover, possibly in response to efforts to discourage trapping and encourage pro-conservation behaviour within protected areas.

Implications for conservation

Our findings highlight the precarious situation of Timneh Parrots in Guinea-Bissau with a small and fragmented population and the majority of individuals aggregated in one area, highlighting the importance of its protection. The Bijagós archipelago was recognised as a UNESCO Biosphere Reserve in 1996 and contains three formally protected areas; the Orango National Park, João-Vieira Poilão Marine National Park (JVPMNP) and the Communitarian Marine Protected Area of the Urok Islands. These protected areas encompass 11 of the islands known to be occupied by Timneh Parrots. To date, initiatives aimed at encouraging pro-conservation behaviour have occurred within these protected areas. These have contributed to increase environmental awareness and have discouraged trapping for the pet trade. Conservation efforts have been particularly targeted within the JVPMNP, which was highlighted as a key site for Timneh Parrots. These efforts have involved working with the local communities who participate in managing the areas along with the national park authority, to protect important habitat features, such as nest trees and discourage the harvesting of chicks from nests. Among other activities, former parrot trappers have been employed to assist with the monitoring and protection of nests and the installation of artificial nest cavities. It is critical that these activities are sustained and opportunities to develop additional incentives for communities, such as ecotourism, are explored. Furthermore, such activities should be accompanied by annual monitoring to track their impact and detect any additional threats. Counts at flyways, reported here, provide a baseline index of local abundance against which future changes can be assessed using a standardised methodology.

Acknowledgements

We are very thankful to Alfredo Simão da Silva, Justino Biai, Emanuel Ramos, Domingos Betunde and Castro Barbosa (from IBAP) for all the support received throughout this project, and to José dos Santos, César Banca, Seco Cardoso, Paulino and Saido for the help when travelling around the islands. Thanks are also due to Edna Correia and Joana Romero, who helped in the collection of data in the field. Funding for this work was provided by the MAVA Foundation through a project granted to IBAP (Institute for Biodiversity and Protected Areas, Guinea-Bissau) – 'La recherche participative au service de la conservation de la biodiversité du Parc National Marin de João

Vieira - Poilão (Archipel des Bijagós)', FCT – Portugal (UID/MAR/04292/2013) granted to MARE - Marine and Environmental Sciences Centre, SOS-Save Our Species through a project granted to The World Parrot Trust - 'Conserving Timneh parrots (*Psittacus timneh*) through protection of key breeding areas and the enforcement of wildlife trade legislation in West Africa', ZooMarine Portugal and The Bridging Peace Foundation.

References

Aleman, J. C., Jarzyna, M. A. and Staver, A. C. (2017) Forest extent and deforestation in tropical Africa since 1900. *Nat. Eco. Evo*. 2: 26–33.

Almada, A. A. (1964) *Tratado breve dos rios de Guiné do Cabo Verde*. A. Brásio, ed. Lisboa: Editorial L. I. A. M.

Amuno, J. B., Massa, R. and Dranzoa, C. (2007) Abundance, movements and habitat use by African Grey Parrots (*Psittacus erithacus*) in Budongo and Mabira forest reserves, Uganda. *Ostrich* 78: 225–231.

Annorbah, N. N. D., Collar, N. J. and Marsden, S. J. (2016) Trade and habitat change virtually eliminate the Grey Parrot *Psittacus erithacus* from Ghana. *Ibis* 158: 82–91.

BirdLife International (2017a) *IUCN Red List for birds*. Available at http://www.birdlife.org [accessed 28 April 2017].

BirdLife International (2017b) *Psittacus timneh* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2017: e.T22736498A118604806. [accessed 28 April 2017].

Breiman, L. (2001) Random forests. *Mach. Learn*. 45: 5–32.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. and Thomas, L. (2007). *Advanced distance sampling*. New York: Oxford University Press.

Campos, A., Monteiro, H. and Catry, P. (2001) Contribuição para o conhecimento do estatuto do Papagaio-cinzento *Psittacus erithacus* no Parque Nacional de Orango (Guiné-Bissau). Unpublished report to IUCN, Bissau.

Catry, P., Barbosa, C., Paris, B., Indjai, B., Almeida, A. and Benoit, L. (2009) Status, ecology, and conservation of sea turtles in Guinea-Bissau. *Chelonian Conserv. Biol*. 8: 150–160.

Catry, P. (2013) Africa's other grey. *PsittaScene* Winter: 13–15.

Cerqueira, M. C., Cohn-Haft, M., Vargas, C. F., Nader, C. E., Abdretti, B. C., Costa, T. V. V., Sberze, M., Hines, J. E. and Ferraz, G. (2013) Rare or elusive? A test of expert knowledge about rarity of Amazon forest birds. *Divers. Distrib*. 19: 710–721.

Clemmons, J. R. (2003) Status survey of the African Grey Parrot (*Psittacus erithacus timneh*) and development of a management program in Guinea and Guinea-Bissau. Geneva: CITES.

Collar, N. J. (2013). Timneh Parrot and Grey Parrot represent two species. Available at http://stuartmarsden.blogspot.pt/2013/12/timneh-parrot-and-grey-parrot-represent.html [accessed on 22 January 2018].

Cuq, F. 2013. Un système d'information géographique pour l'aide à la gestion intégrée de l'archipel des Bijagós (Guinée-Bissau). *J. Chem. Inf. Model*. 53: 1689–1699.

Dändliker, G. (1992) Le Perroquet gris (*Psittacus erithacus*) en Guinée: Évaluation des populations, contribution à la biologie, étudo de l'exploitation commerciale et recommandations pour la gestion. Geneva: CITES.

Danielson, F., Burgess, N. D. and Balmford, A. (2005) Monitoring matters: examining the potential of locally-based approaches. *Biodivers. Conserv*. 14: 2507–2542.

del Hoyo, J., Collar, N. J., Kirwan, G. M. and Sharpe, C. J. (2018) Timneh Parrot (*Psittacus timneh*). In J. del Hoyo, A. Elliot, J. Sargatal, D. A. Christie, E. de Juana, eds. *Handbook of the birds of the world alive*. Barcelona: Lynx Edicions. Available at https://www.hbw.com/node/467496 [accessed on 22 January 2018].

Dénes, F. V, Tella, J. L. and Beissinger, S. R. (2018) Revisiting methods for estimating parrot abundance and population size. *Emu* 118: 1–13.

Dodman, T., Barlow, C., Sá, J. and Robertson, P. (2004) *Zonas Importantes para as Aves na Guiné-Bissau/Important Bird Areas in Guinea-Bissau*. Dakar: Wetlands International.

Fotso, R. (1998a) Étude sur l'état, la répartition géographique et l'utilisation du perroquet gris (*Psittacus erithacus*) dans la République démocratique du Congo. Geneva: CITES.

Fotso, R. (1998b) Survey status of the distribution and utilization of the Grey Parrot (*Psittacus erithacus*) in Cameroon. Geneva: CITES.

Goodman, L. A. (1961) Snowball sampling. *Ann. Math. Stat.* 32: 148–170.

Hadfield, J. D. (2010) MCMC methods for multi- response generalized linear mixed models: the MCMCglmm R package. *J. Stat. Soft.* 33: 1–22.

Heinsohn, R., Buchanan, K. L. and Joseph, L. (2018) Parrots move to centre stage in conservation and evolution. *Emu* 118: 1–6.

Henriques, M. and Lopes, D. C. (2014) Bananas, the survivor. *PsittaScene* Autumn: 15–16.

Hijmans, R. J. (2015) *raster: Geographic data analysis and modeling*. R package version 2.3-40. Available at https://CRAN.R-project.org/package=raster.

Huang, C., Wylie, B., Yang, L., Homer, C. and Zylstra, G. (2002) Derivation of a tasselled cap transformation based on Landsat 7 at-satellite reflectance. *Int. J. Remote. Sens.* 23: 1741–1748.

IUCN (2012) *IUCN Red List Categories and Criteria: Version 3.1*. Second edition. Gland, Switzerland and Cambridge, UK: IUCN.

Jones, J. P. G., Andriamarovololona, M. M., Hockley, N., Gibbons, J. M. and Milner-Gulland, E. J. (2008) Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. *J. Appl. Ecol.* 45: 1205–1212.

Kuhn, M. (2015) *caret: Classification and Regression Training*. R package version 6.0-47. Contributions from J. Wing, S. Weston, A. Williams, C. Keefer, A. Engelhardt, T. Cooper, Z. Mayer, B. Kenkel, the R Core Team, M. Benesty, R. Lescarbeau, A. Ziem and L. Scrucca Available at http://CRAN.R-project.org/package=caret.

Limoges, B. and Robillard, M. (1991) Proposition d'un plan d'aménagement de la réserve de la biosphère de l'archipel des Bijagós. Vol. 1 - Les secteurs de développement, zonages et recommandations. Gland : UICN.

Lopes, D. C., Henriques, M., Monteiro, H., Martin, R. O. and Catry, P. (2018b) Papagaio-cinzento-de-timneh – um tesouro das florestas bijagós. In P. Catry and A. Regalla, eds. *Parque Nacional Marinho João Vieira e Poilão: Biodiversidade e Conservação*. Bissau: IBAP – Instituto da Biodiversidade e das Áreas Protegidas.

Lopes, D. C., Martin, R. O., Henriques, M., Monteiro, H., Regalla, A., Tchantchalam, Q., *et al.* (2018a) Nest-site characteristics and aspects of the breeding biology of the endangered Timneh Parrot *Psittacus timneh* in Guinea-Bissau. *Ostrich* 89: 33–40.

Marsden, S. J., Loqueh, E., Takuo, J. M., Hart, J. A., Abani, R., Ahon, D. B., Annorbah, N. N. D., Robin, J. and Valle, S. (2015) Using encounter rates as surrogates for density estimates makes monitoring of heavily-traded Grey parrots achievable across Africa. *Oryx* 50: 617–625.

Marsden, S. J. and Royle, K. A. Y. (2015) Abundance and abundance change in the world 's parrots. *Ibis* 157: 219–229.

Martin, R. O. (2018a) The wild bird trade and African parrots: past, present and future challenges. *Ostrich* 89: 139–143.

Martin, R. O. (2018b) Grey areas: temporal and geographical dynamics of international trade of Grey and Timneh Parrots (*Psittacus erithacus* and *P. timneh*) under CITES. *Emu* 118: 1448–5540.

Martin, R. O., Perrin, M. R., Boyes, R. S., Abebe, Y. D., Annorbah, N. D., Asamoah, A., *et al.* (2014) Research and conservation of the larger parrots of Africa and Madagascar: a review of knowledge gaps and opportunities. *Ostrich* 85: 205–233.

McGowan, P. (2001) *Status, management and conservation of the African Grey Parrot Psittacus erithacus in Nigeria*. Geneva, Switzerland: CITES.

Mittermeier, R. A., Gil, P. R., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., Lamoreux, J. and da Fonseca, GAB. (2004) *Hotspots revisited – Earth's biologically richest and most endangered terrestrial ecoregion*. Mexico City: CEMEX.

Naurois, R. (1981) La distribution géographique du perroquet gris *Psittacus erythacus timneh*. *Malimbus* 3: 59–61.

Olah, G., Butchart, S. H. M., Symes, A., Guzmán, I. M., Cunningham, R., Brightsmith, D. J. and Heinsohn, R. (2016) Ecological and socio-economic factors affecting extinction risk in parrots. *Biodiv. Conserv.* 25: 205–223.

Parry, L. and Peres, C. A. (2015) Evaluating the use of local ecological knowledge to monitor

hunted tropical-forest wildlife over large spatial scales. *Ecol. Soc.* 20: 15.

Perrin, M. (2012) *Parrots of Africa, Madagascar and the Mascarene Islands - biology ecology and conservation*. Johannesburg: Wits University Press.

Predavec, M., Lunney, D., Hope, B., Stalenberg, E., Shannon, I., Crowther, M. S. and Miller, I. (2016) The contribution of community wisdom to conservation ecology. *Conserv. Biol.* 30: 496–505.

R Core Team (2015) *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing.

Rodwell, S. P. (1996) Notes on the distribution and abundance of birds observed in Guinea-Bissau, 21 February to 3 April 1992. *Malimbus* 18: 25–43.

Surowiecki, J. (2005) *The wisdom of crowds: Why the many are smarter than the few and how collective wisdom shapes business, economics, societies and nations*. New York: Anchor Books.

Sutherland, W. J., Newton, I. and Green, R. E. (2004) *Bird ecology and conservation - A handbook of techniques*. New York: Oxford University Press.

Turvey, S. T., Barrett, L. A., Yujiang, H., Lei, Z., Xinqiao, Z. and Xianyan, W. (2010) Rapidly shifting baselines in Yangtze fishing communities and local memory of extinct species. *Conserv. Biol.* 24: 778–787.

Valle, S., Collar, N. J., Harris, W. E. and Marsden, S. J. (2017) Spatial and seasonal variation in abundance within an insular grey parrot population. *Afr. J. Ecol.* 55: 433–442.

Valle, S., Collar, N. J., Harris, W. E. and Marsden, S. J. (2018) Trapping method and quota observance are pivotal to population stability in a harvested parrot. *Biol. Conserv.* 217: 428–436.

DANIEL C. LOPES[1]*, MOHAMED HENRIQUES, PAULO CATRY
MARE – Marine and Environmental Sciences Centre, ISPA – Instituto Universitário, Rua Jardim do Tabaco 34 1149-041 Lisbon, Portugal.
[1]*and Faculty of Sciences, University of Lisbon, Campo Grande, 1749-016 Lisbon, Portugal.*

ROWAN O. MARTIN
World Parrot Trust, Glanmor House, Hayle, Cornwall, TR27 4HB, UK; and Percy FitzPatrick Institute of African Ornithology, DST/NRF Centre of Excellence, University of Cape Town, Cape Town, South Africa.

HAMILTON MONTEIRO
Coastal Planning Office, Guinea-Bissau.

PAULO CARDOSO
Bioinsight, Lda., Rua Antero de Quental, n°52, 2675-690 Odivelas, Portugal.

QUINTINO TCHANTCHALAM, ANTÓNIO J. PIRES, AISSA REGALLA
IBAP - Institute of Biodiversity and Protected Areas, Avenida Dom Settimio Arturo Ferrazzetta, Caixa Postal n° 70, Bissau, Guinea-Bissau.

**Author for correspondence; e-mail: daniel.da.costa.lopes1@gmail.com*

Received 21 April 2018; revision accepted 31 August 2018;
Published online 3 October 2018