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Distribution, ecology and conservation status of the Blue-headed Macaw *Primolius couloni*

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ABSTRACT

Until recently thought to be secure (i.e. Least Concern), the Blue-headed Macaw is now classified as Endangered in the IUCN Red List, based on an apparent decline and a population estimate of <2500 mature individuals. We review published and unpublished sources, collating records from 61 localities in Peru, Brazil and Bolivia, and compiling information on habitat use, seasonality, group size, demography, and population density. We find the species to be associated with disturbed habitats at one site, but a broader analysis revealed no significant associations with forest type, riverine habitats, degree of disturbance or altitude. By mapping locality records, and accounting for discontinuities, we calculate an Extent of Occurrence of 460,000 km^2. Range-wide data on encounter rates and flock sizes suggest that the species is sedentary and gregarious, with an overall population density of one mature individual per 10–50 km^2. Our figures for range size and density (both highly conservative) indicate that the global population estimate should be revised upwards to 9200–46,000 mature individuals. Balanced against an increasing threat from trade, these data argue for a reversal in status to Vulnerable, with a shift to Near Threatened possible in future. Given these recent fluctuations in conservation status, the Blue-headed Macaw provides valuable insight into the difficulties of using IUCN Red List criteria to assess poorly known taxa. Red List assessments should be based on extensive reviews where possible, and analyses using Red List data should consider effects of data quality.

1. Introduction

The Blue-headed Macaw was not considered to be a conservation priority until the 21st century. It was rare in captivity (CITES, 2002), while specimen records and published accounts suggested that it was fairly widespread and tolerant of habitat alteration (Parker and Remsen, 1987; Juniper and Parr, 1998). Accordingly, it was not listed in recent global status assessments and Red Data Books (Collar et al., 1992, 1994; BirdLife International, 2000), nor was it included in the latest parrot conservation action plan (Snyder et al., 2000). Only recently has it been recognised how little is known about this species: there are few specimens, all from Peru, and it is thought to be scarce and declining throughout its range (BirdLife International, 2007a). On the IUCN Red List of threatened species (henceforth 'Red List') it was reclassified from "Least Concern" to "Near Threatened" in 2004 (BirdLife International, 2004), and then jumped a rank to "Endangered" in 2006 (IUCN, 2006). It was also recently upgraded to CITES Appendix I (CITES, 2002, 2003).

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These shifts in treatment are based on few data. When Collar (1998) surveyed the global literature on parrots, scoring the quantity and quality of information published for each species, the genus *Primolius* (then treated as *Propyrrhura*) came last amongst all 83 genera. It forms a superspecies containing two other species, Blue-winged Macaw *P. maracana* and Yellow-collared Macaw *P. auricollis* (Sibley and Monroe, 1990; Collar, 1997), and of these three species the Blue-headed Macaw is the least well known. Recent publications show its range in southern Amazonian Peru, with minor extensions into Brazil and Bolivia (Collar, 1997; Juniper and Parr, 1998). Using these published distributions, BirdLife International (2007a) estimated the extent of occurrence to be 373,000 km^2. Similarly, on the basis of a few published sources and anecdotal accounts, Lambert et al. (1993) made a rough population estimate of 10,000 individuals in 1990. More recently, Gilardi (2003) commented that "the available concrete information on abundance" suggested a global population of "well under 1000 mature individuals". He added that the majority of principal watersheds in which this species is thought to occur "have been visited by ornithologists, birders and biologists in general", and that they found the species to be "absent or extremely rare". Based on this new information, BirdLife International (2007a) revised their global population estimate downwards to 1000–2499 mature individuals in 2005, and reclassified the species as Endangered under IUCN Red List criterion C2a(i), with two explicit caveats: that the data were poor and that further changes in classification may be necessary.

These assessments have far-reaching consequences. The Red List, produced by the Species Survival Commission (SSC) of IUCN – the World Conservation Union, provides a baseline for prioritising conservation actions (Collar, 1996; Rodrigues et al., 2006), and measuring their success (Butchart et al., 2004, 2005). As the most authoritative and objective assessment of extinction risk in animals and plants, it has a growing influence on funding, legislation and research. For example, the projects supported by the Critical Ecosystem Partnership Fund (http://www.cepf.net) and the BP Conservation Programme (http://conservation.bp.com/) have been selected, at least in part, on the basis of the globally threatened species they are targeted to preserve. Red List data are widely used in national development policies, legislation, and multilateral agreements (Rodrigues et al., 2006), as well as many influential research articles (e.g. Purvis et al., 2000; Root et al., 2003; Butchart et al., 2004; Eken et al., 2004; Rodrigues et al., 2004; Stuart et al., 2004; Thomas et al., 2004; Ricketts et al., 2005). Moreover, a recent World Conservation Congress passed a resolution (RESWCC3.013) mandating the development of new uses for the Red List in national legislation, international conventions, conservation planning and scientific research (IUCN, 2005).

The Red List carries much weight, and rightly so, but how robust are the assessments on which it is based? The criteria have been honed and re-honed (Mace and Lande, 1991; IUCN, 2001), but the assessment process still draws criticism (Possingham et al., 2002; Regan et al., 2005), as does the correct handling and application of population data (Broderick et al., 2006). More than a decade after the implementation of data-driven and objective criteria for estimating extinction risk (IUCN, 2001; Rodrigues et al., 2006), some critics still hold that "the Red List's categorizations are largely informed guesswork by experts" (Harcourt, 2005).

Given recent changes in status, the Blue-headed Macaw provides a useful case study of the Red List process, particularly the difficulty of classifying poorly known species. To re-assess its global conservation status we reviewed all accessible information from published and unpublished sources. We compiled ecological data, such as habitat preferences, clay lick usage and breeding behaviour, where these were relevant to conservation. On the basis of a range-wide review of locality data, we estimated its distribution and population size, re-applied the Red List criteria, and used our findings to formulate constructive comments about the Red List process.

2. Methods

2.1. Locality and record data

Early locality records for the Blue-headed Macaw were collected from museum data and publications. Since 1990, an increase in regional research and ecotourism has produced new records, many of them unpublished, or published outside the peer-reviewed literature. We sought personal accounts from researchers and experienced ornithologists, and referred to the reports of conservation and scientific expeditions, including several documents published online by the Rapid Assessment Program of Conservation International, and the Rapid Biological Inventory program of the Chicago Field Museum. For a full list of sources, see Supplementary data.

Where sites were tightly packed (<20 km between sites) we pooled them under a single locality: for example, "Camisea" is an assemblage of five sites along or near the upper Río Urubamba, and "Lower Río Tambopata" includes nine sites. Thus, while we used a total of 51 sources to produce a list of 61 separate localities, the actual number of sites was considerably higher (>100). To measure regional coverage, we noted all localities that had received recent intensive surveys (>1 week of fieldwork at a single site by experienced personnel, post-1970) but for which no records of Blue-headed Macaw are known.

2.2. Flock size and population estimates

For each post-1970 locality we estimated minimum population size and maximum flock size. In most cases we assumed that non-simultaneous sightings of different flocks could involve the same birds, and therefore the maximum flock size reported is used as the minimum population size. Where flocks were seen at sites more than 10 km apart, we used a cumulative figure of the largest flocks at each site to generate a minimum population size; where largest flock size was not reported we made an estimate of the minimum number of birds likely to have produced the pattern of records. For localities where birds were recorded but where no population estimate was made, we assumed a minimum of one pair at each site. In almost all cases these figures are certain to underestimate the true number of birds present.

We calculated average group size using data from four sites where observers recorded encounters systematically; non-systematic sampling was assumed to produce skewed data because observers tend to report the largest groups. The resulting data set included 136 observations from Tambopata Research Center (DJB and team), Las Piedras Biological Station (A. Lee and E. Tatum-Hume), the Manu Learning Center (C. Torres-Sovero and E. Tavera), and Posada Amazonas (C. Torres-Sovero, A. Bravo, DJB and team; see Fig. 1). To test for seasonal changes in flock size, we compared data across four periods: December–February (wet season), March–July (end of wet season and early dry season), August–September (late dry season) and October–November (dry to wet transition).

2.3. *Range size*

The Red List criteria (IUCN, 2001) define Extent of Occurrence (EOO) as “the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon”. This measure may exclude discontinuities or disjunctions within the overall distributions of taxa (e.g. large areas of unsuitable habitat). To generate an EOO for the Blue-headed Macaw we mapped a boundary around localities using ArcView GIS 3.2a (ESRI, 2005), and accounted for discontinuities by subtracting all major areas of inappropriate habitat (deforestation, settlements, land over 1500 m asl, large peripheral regions with no records etc.). We then rounded

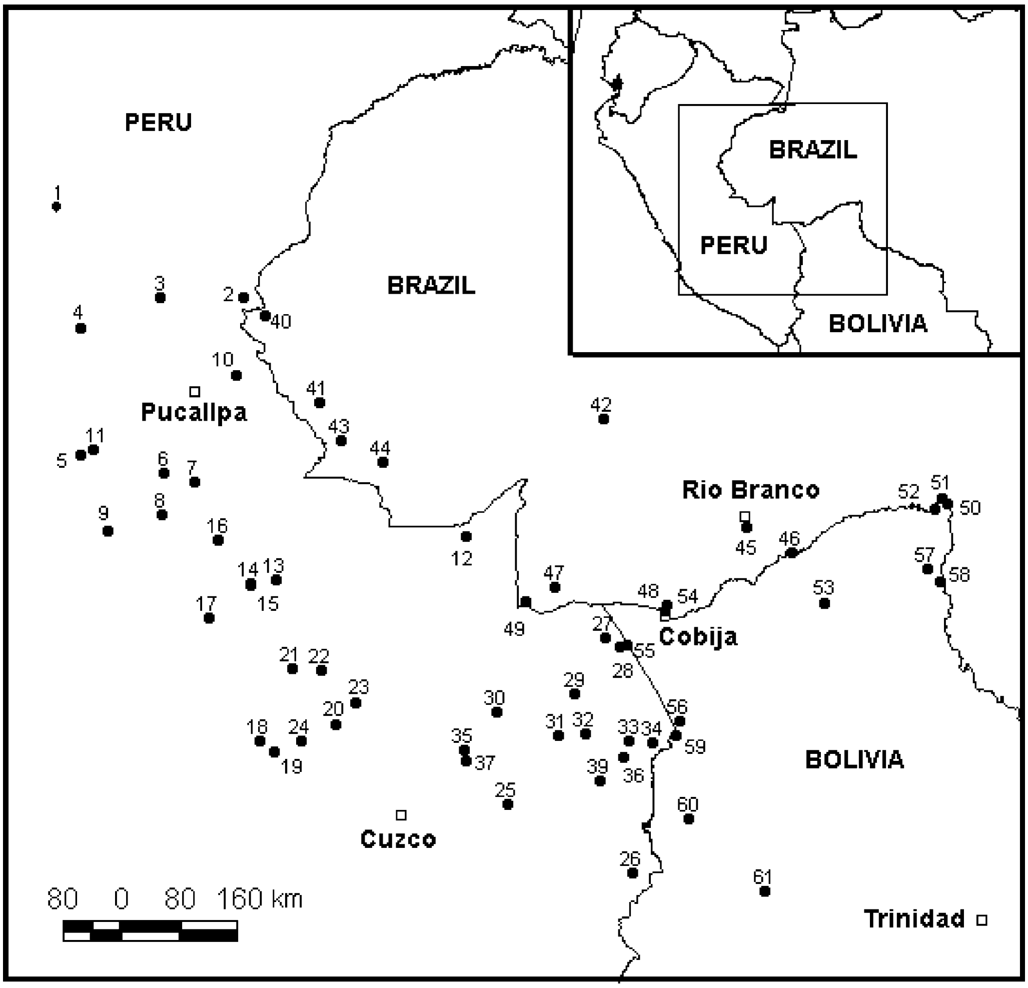

Fig. 1 – Localities for the Blue-headed Macaw, listed from north to south within political unit: (1) Shanusi; (2) Río Alto Tapiche; (3) Aguas Calientes; (4) Cordillera Azul; (5) Tingo Maria; (6) Puerto Inca; (7) Chinchavito; (8) Puerto Victoria; (9) Pozuso; (10) Río Shesha; (11) Fundo Cinchona; (12) Balta; (13) Pucani; (14) Santa Rosa; (15) Atalaya; (16) Villa América; (17) Río Apurímac; (18) Luisiana; (19) Huananay; (20) Río Urubamba; (21) Tangoshiari; (22) Camisea; (23) Kapiromashi; (24) Kepashiato; (25) Hacienda Cadena; (26) San Juan del Oro; (27) Oceania; (28) San Lorenzo; (29) Las Piedras Biological Station; (30) Río Manu; (31) CICRA; (32) Lagarto; (33) Puerto Maldonado; (34) Enahuipa; (35) Shintuya; (36) Lower Río Tambopata; (37) Atalaya; (38) Consuelo; (39) Upper Río Tambopata; (40) Serra da Jaquirana; (41) Rio Juruá-mirím; (42) Seringal Sarginha; (43) Boca do Tejo; (44) Restauração; (45) Rio Branco; (46) Placido de Castro; (47) Rio Iaco; (48) Brasileia; (49) Estação Ecológica do Rio Acre; (50) Abunã; (51) Manoa; (52) Fortaleza; (53) Ingavi; (54) Cobija; (55) Extrema; (56) Chive; (57) Cachuela Esperanza; (58) Río Yata; (59) Río Heath; (60) Río San Antonio; (61) Rurrenabaque. Details of records, coordinates and source are given in Supplementary data.

the outcome to the nearest 10,000 km^2 to produce an EOO estimate.

2.4. *Habitat and altitudinal range*

Habitat descriptions were available for >75% of post-1970 localities. In these cases we assigned localities to one of three habitat types (floodplain, upland, or a mix of the two), one of three anthropogenic disturbance regimes (pristine, moderately disturbed, or heavily disturbed), and one of two elevational ranges (lowlands <500 m, or foothills $\geqslant$500 m asl). We chose 500 m as the cut-off point as the Andes generally rise steeply from this altitude upwards, and Amazonia drops gradually from this point downwards. We compared minimum population estimates and maximum flock sizes at each locality for each variable.

Determining habitat associations for psittacines is complicated because they are often seen in flight above potentially suboptimal habitat; for example, a population of Blue-winged Macaws bred in relatively intact forest, but ranged daily over cleared areas and agricultural land (Evans et al., 2005). Further, although many Amazonian parrots are seen from rivers or near rivers, this may be because most surveys or expeditions do not penetrate far inland. Added to this sampling bias, there is a detectability bias as parrots are usually seen and identified most readily from rivers and clearings. As a result, our multi-site analysis of habitat association is relatively crude, especially as most localities contain a mosaic of habitats.

To clarify patterns of habitat use at a local scale, we assigned all observations at one site, Centro de Investigación y Capacitación Río Los Amigos (CICRA 2004–2006; see Supplementary data), to two general habitat types (disturbed or non-disturbed forest). As observations of flying birds tell us little about habitat usage, we separated CICRA data into two subsets (perched and flying); as observer time was split roughly equally between disturbed and non-disturbed areas, we compared our results against an expected 50:50 pattern. Degraded forest at CICRA generally consisted of small man-made clearings, or scattered tall trees standing over extensive low regrowth with much bamboo and grasses (mainly *Guadua* cf. *weberbaueri* and *Ichnanthus breviscrobs*; J. Janovec pers. comm.). Most birds were located and identified by voice, therefore biases affecting visual data do not apply. Blue-headed Macaws, like most parrots, call loudly and distinctively in flight and when perched.

2.5. *Clay lick usage*

To assess year-round presence and seasonal fluctuations in population size at a single locality, activity was recorded at a clay lick adjacent to Tambopata Research Center from nautical sunrise until the birds finished their morning lick use (usually before 07:30 EST) on 1468 mornings from 12 January 2000 to 31 December 2005. On every morning, observers noted the time Blue-headed Macaws were first detected near the lick; this species often visited the vicinity of the lick without actually feeding on the clay.

2.6. *Encounter rates*

We calculated encounter rates of Blue-headed Macaws from 798.5 h of systematic parrot counts at five sites. These included over 3000 10-min point counts at Tambopata Research Center (DJB and team), 83 h of observations from a 43-m tall canopy tower at Posada Amazonas (DJB and team), 45 h of observations in a clearing at CREES (C. Torres-Sovero and E. Tavera), 65 h of observations from a cliff-top viewpoint at Las Piedras Biological Station (A. Lee and E. Tatum-Hume), and 85 h of observations from the CICRA station clearing (JAT).

2.7. *Statistics*

Data were compared using univariate nonparametric techniques: Mann–Whitney *U*-test for altitudinal variation, Kruskal–Wallis tests for habitat and disturbance, ANOVA for variations in flock size, and χ^2-tests for habitat use at CICRA. All statistical tests were carried out using SPSS (2001); *p*-values are two-tailed.

3. Results and discussion

3.1. *Distribution, population and ecology*

3.1.1. *Range size*

We compiled records from 23 published sources, 22 unpublished sources, and six museums, resulting in a total of 61 localities (Fig. 1; see Supplementary data). One of these, Shanusi, is based on a specimen record from 1885, and lies outside the scatter of recent records (Fig. 1). Given the possibility that the specimen was mislabelled, or the locality misidentified, we removed it from our analysis of range size. We estimate a total global range of 609,494 km^2 and an EOO of 460,000 km^2 (see Section 2).

This EOO, 60% larger than the previously published estimate (BirdLife International, 2007a), is probably an underestimate. The total global range remains $\geqslant$90% forested, with the only significant areas of perturbation being around the largest city, Puerto Maldonado, Peru, and between Iñapari and Rio Branco, Brazil (FlashEarth, 2006). The fact that the Blue-headed Macaw is still seen on the outskirts of Puerto Maldonado suggests that anthropogenic pressures have not eliminated it from any large areas. Thus, we may have overestimated discontinuities in range when producing our EOO estimate. There is also a shortage of data from Acre, Brazil, and this part of the range may be considerably more extensive.

3.1.2. *Altitudinal range*

Localities range in elevation from 200 m to 1500 m, but the majority lie below 500 m (41 versus 16; 72%; see Supplementary data). This disparity reflects the fact that that >90% of the range mapped in Fig. 1 lies below 500 m. Minimum estimated population sizes and maximum flock sizes were slightly higher above 500 m, but this difference was not significant (Table 1; Fig. 2a). This result tallies with the observation that relatively dense populations are found in both foothill regions (e.g. mountains of Huánuco) and lowlands far from the base of the Andes (e.g. Los Amigos, Tahuamanu, Purús and Juruá rivers). Similarly, the two largest flocks recorded were c.60 birds at Pozuso (850 m) and 53 birds at San Lorenzo

Table 1 – Minimum population size and maximum flock size reported for Blue-headed Macaw populations, partitioned by altitude, habitat and degree of habitat degradation

		Minimum population size	N	Maximum group size	N
Altitude	<500 m	8.9 ± 13.1 (2–60)	44	8.3 ± 10.3 (2–53)	29
	⩾500 m	9.9 ± 14.6 (2–60)	17	11.4 ± 15.8 (1–60)	14
	U	327		179	
	p	0.44		0.52	
Habitat	Upland	9.2 ± 14.6 (2–60)	15	9.8 ± 15.6 (1–60)	13
	Floodplain	8.1 ± 13.0 (2–60)	23	6.0 ± 4.9 (2–20)	17
	Floodplain +upland	17.2 ± 18.2 (2–53)	9	14.6 ± 17.1 (2–53)	8
	χ^2_2	4.1		1.2	
	p	0.13		0.55	
Disturbance	Pristine	5.1 ± 3.7 (2–12)	11	5.3 ± 3.7 (2–12)	8
	Moderately degraded	8.2 ± 10.3 (2–42)	21	7.1 ± 6.7 (1–20)	17
	Highly degraded	13.0 ± 18.2 (2–60)	15	10.8 ± 14.1 (2–53)	12
	χ^2_2	1.7		1.0	
	p	0.43		0.61	

Values given are mean ± SD (with range in brackets). Comparisons are made using Mann–Whitney *U* test for altitude and Kruskal–Wallis test for habitat and degradation.

(250 m), suggesting no difference in overall abundance in lowlands versus foothills. This pattern may not hold true on a local scale, as the species is fairly common on or near low (<1000 m) ridges in Manu National Park, but much rarer in lowlands to the east (B. Walker *in litt.*, 2005, JAT). Its distribution in this well-studied region may have given rise to speculation that the Blue-headed Macaw "possibly prefers foothill to lowland forest" (Juniper and Parr, 1998). Our range-wide analysis suggests that this impression was a sampling artefact.

3.1.3. *Association with rivers*

Minimum estimated population size and maximum flock size tended to be larger in localities classified as a mixture of floodplain and uplands, than those classified as either solely floodplain or solely uplands, but this relationship was not significant (Table 1; Fig. 2b). At Cocha Cashu, Peru, the species was recorded regularly from transitional forest (the intermediate zone between early successional riverine regrowth and mature floodplain forest), *Mauritia flexuosa* palm swamps, and mature floodplain forest (Terborgh et al., 1990). At Tambopata Research Center it was recorded 28 times during systematic censuses by DJB, in floodplain forest (29% of records), palm swamps (21%), successional/transitional habitats (32%) and *terra firme* (17%), suggesting a broad spectrum of habitat use. Some authors suggest that the species may prefer riverine habitats (Collar, 1997; Juniper and Parr, 1998), with one stating that it is "obviously bound to rivers" (CITES, 2002), but our findings provide little support for this.

3.1.4. *Association with disturbed habitats*

Minimum estimated population size and maximum flock size averaged larger in disturbed areas than pristine areas, but this trend was not statistically significant (Table 1; Fig. 2c). At CICRA, we found that 62% of 226 encounters were made in degraded habitats, significantly more than predicted by chance ($\chi^2 = 13.9$, df = 1, $p < 0.0001$). When only perched birds were considered, 88.6% of 44 encounters were in degraded forest ($\chi^2 = 26.3$, df = 1, $p < 0.0001$). Our data would be skewed if birds perching at edges and clearings were more detectable than birds perching in dense forest. However, this species is highly vocal in flight, and often vocal when perched (especially just before take-off or after landing), and was almost always detected by vocal cues rather than visual cues. We found no evidence to suggest that birds called less in dense forest.

Almost two decades ago, Parker and Remsen (1987) stated that "this macaw seems to survive in cutover areas with scattered patches of forest and may be expanding its rather small range in south-western Amazonia". More recently, Juniper and Parr (1998) concluded on the basis of a literature review that the species preferred "disturbed or partly open habitats with birds mostly occurring at forest edge along rivers, in clearings and around partly forested settlements". Vriesendorp et al. (2004) espoused a different view, stating that it is "sensitive to human disturbance, occurring only in large tracts of primary lowland and foothill forest". Our data suggest that the species is associated with degraded areas, at least locally, but that it occurs in many vegetation types.

3.1.5. *Use of clay licks*

The species eats soil at clay licks, possibly as a source of sodium or to protect it from dietary toxins (Brightsmith, 2004; Brightsmith and Aramburú, 2004). Use of these licks varies regionally and seasonally, for unknown reasons. It is generally a rare visitor to the main clay licks on the Río Manu (e.g. near Cocha Cashu), Río Madre de Dios (e.g. Blanquillo), and Río Heath, as well as at several other smaller clay licks in Dpto. Madre de Dios (Gilardi, 2003; A. Lee *in litt.*, 2006; JAT). However, it is now known to be a regular visitor to mineral licks on the middle stretch of Río Urubamba and the upper Río Madre de Dios (Valqui, 2004; BirdLife International, 2007a; A. Lee *in litt.*, 2006; C. Torres-Sovero, unpubl. data).

At the large clay lick near Tambopata Research Center, the species was seen in the vicinity of the clay lick on 25% of 1468 mornings, and ate soil on 9% of those mornings. The population at this site has apparently been increasing, with birds seen or heard in the area of the clay lick on <10% of mornings in 2000 and 2001, and on >55% of the mornings in 2005 (Fig. 3).

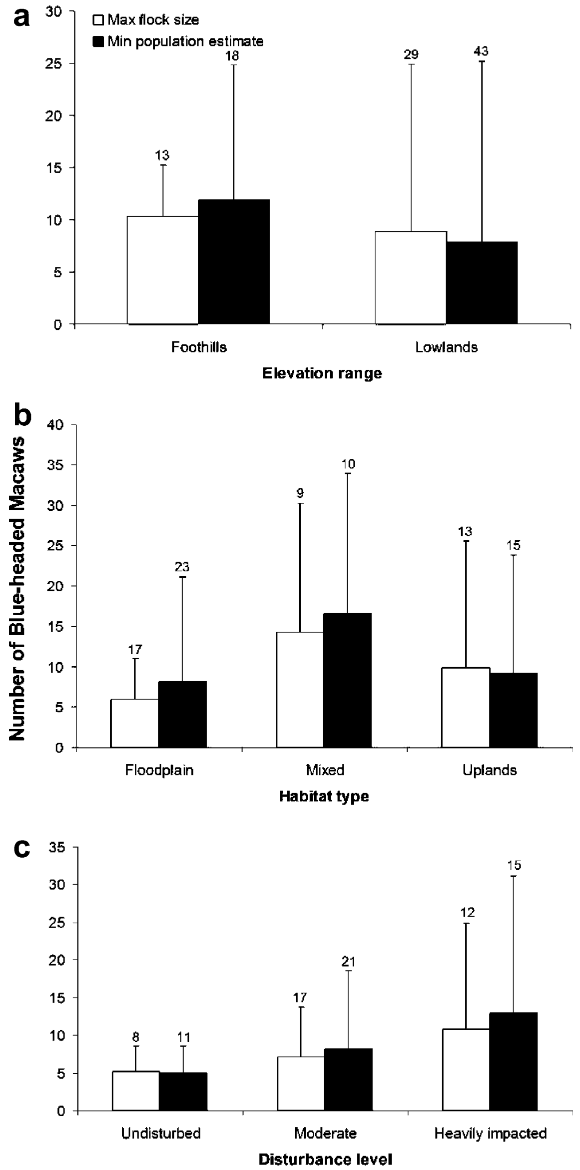

Fig. 2 – Comparison of mean maximum flock size and mean minimum estimated population size for Blue-headed Macaws at all localities. Each locality was classified by its altitude (a), habitat type (b), and anthropogenic disturbance intensity (c, see Section 2). Some data were unavailable, resulting in uneven sample sizes. Maximum flock size is greater than minimum population size because some areas with small minimum population sizes did not report flock size data. Error bars represent 1SD; numbers above error bars are sample sizes. None of the differences among means are significant ($p > 0.05$).

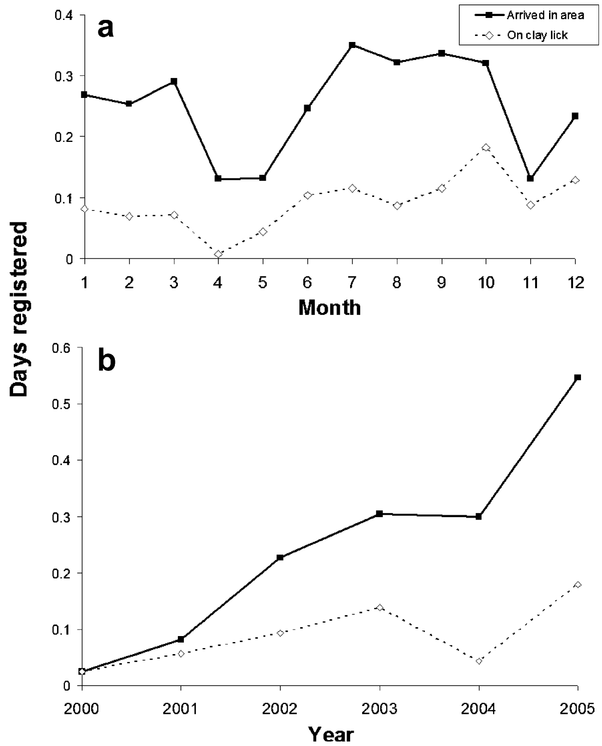

Fig. 3 – Seasonal patterns of clay lick use for Blue-headed Macaw at Tambopata Research Center, south-eastern Peru (a). Observations of the species at this clay lick, analysed by month (b).

The reason why this species has increased is unclear, the only major change being the natural die-off in 2002 of hundreds of hectares of *Guadua* sp. (Poaceae) bamboo in the *terra firme* forest surrounding the clay lick (Griscom and Ashton, 2003). This die-off has created large areas of vine tangles and second-growth forest, and may have increased the abundance of food plants. Use of the nearby clay lick by Blue-headed Macaws varies seasonally: high from June to December (dry season and early wet season), then trailing off to a low in April–May at the end of the wet season (Fig. 3). This month-by-month pattern is broadly similar to that found in other psittacines at the same site, but it is not known whether these fluctuations relate to seasonal variations in population size and breeding behaviour, or to variations in dietary needs (Brightsmith, 2004).

Clay-lick usage is an important consideration from a conservation perspective because parrots visiting traditional sites are vulnerable to trapping if protection is not enforced. Our results show that clay lick usage by Blue-headed Macaws is regular at several sites, and occurs year-round at Tambopata, with possible seasonal fluctuations in overall numbers. This suggests that density estimates can be extrapolated range-wide (see Section 3.1.8), but need to be controlled for seasonal variation.

3.1.6. *Flocking behaviour*

The species is not considered gregarious, and is only reported to occur "in pairs or groups of three" (Juniper and Parr, 1998). Its tendency to form flocks seems to be greatly understated, however, as the largest gatherings reported here were groups of 53 individuals at San Lorenzo, Madre de Dios, Peru (E. Salazar *in litt.*, 2006), and of c.60 individuals, with more nearby, at Pozuso, Huánuco, Peru (G. Engblom *in litt.*, 2005). Groups containing 10 or more individuals have been reported from 13 different localities, including CICRA, where flocks of this size are regularly encountered, at least seasonally (D. J. Lebbin *in litt.*, 2005). Flocks of four or more individuals are routinely reported throughout the global range and make up 32% of the 136 sightings reported in this study.

Large groups are a regular feature, but small groups are much more common. Group sizes across Madre de Dios, Peru averaged 2.89 ± 2.11 individuals (median = 2, mode = 2, minimum = 1, maximum = 17, N = 136 groups detected during systematic observations at four sites). Average group sizes ranged from a low of 2.63 ± 1.61 individuals in the wet season to a high of 3.34 ± 2.16 in the dry–wet transition, but variation across all four seasons was not statistically significant (ANOVA: $F_{3,132} = 0.098$, N = 136 groups, $P = 0.40$). Comparing group size among different sites we found that average group size was slightly lower at CREES (Manu Learning Center) on the Río Madre de Dios (2.05 ± 0.85, N = 19 groups) than on the lower Río Tambopata (3.06 ± 3.02, N = 31) and Tambopata Research Center (2.99 ± 1.91, N = 82), but these differences were not statistically significant (ANOVA: $F_{2,129} = 1.66$, $p = 0.19$). One additional data-set from the Tambopata region gave an average flock size of 1.8 (N = 28 sightings; CITES, 2002; Lloyd, 2004); this seems remarkably low given that the species usually travels in pairs.

3.1.7. *Breeding*

The Blue-headed Macaw is reported to have low reproductive output in the wild (CITES, 2002), but this statement is based on few data. A recent review of breeding records for south-eastern Peruvian parrots found no published or unpublished records for this species, but reported 55 nests of Scarlet Macaw *Ara macao* and 75 nests of Blue-and-yellow Macaw *Ara ararauna* (Brightsmith, 2005). One possible nest was reportedly in a bamboo cavity (CITES, 2002), and another was in a tree cavity repeatedly visited by a pair of adults in the Cordillera Azul (Alverson et al., 2001). A young chick seen accompanying parents at the clay lick at Tambopata Research Center in July 2005 (J. Lascurian *in litt.*, 2005), and one pair out of 10 pairs cared for a single young in April at Manu National Park (Machado de Barros, 1995).

In captivity, clutch size is reported to be 2–4 eggs (Vit, 1997). A captive female in Lima, Peru, produced two clutches of three eggs (A. Cáceres *in litt.*, 2006), and mean clutch size was 3.07 ± 0.62 in a captive population at Loro Parque Fundación, Tenerife, Spain (N = 14 clutches; D. Waugh *in litt.*, 2006). At Loro Parque, pairs produced 0.93 clutches per annum, and mean age of first breeding was 4.1 ± 1.03 years (range = 2.5–5 years, N = 7), such that a seed population of two pairs, received in the 1990s, produced a population of 35 individuals after only seven years of breeding (D. Waugh *in litt.*, 2006). Adult longevity is unknown, but the congeneric Blue-winged Macaw can live at least 31 years in captivity (Brouwer et al., 2000). Data on reproductive output and longevity need to be confirmed by studies of birds in the wild.

If wild Blue-headed Macaws, like their captive counterparts, have a roughly annual breeding cycle and a relatively young age of first breeding, there should be only three sizeable cohorts of non-breeding birds in the population. The number of adults fluctuates according to survivorship and productivity, and the adult-immature ratio in most macaws seems likely to be between 1:1 and 5:1 (J. Gilardi *in litt.*, 2006). Given the information outlined above, we adopt an estimated adult-immature ratio of 4:1 for the Blue-headed Macaw.

3.1.8. *Movements*

There is little information on movements in this species. Birds have consistently been observed around Tingo Maria, Huánuco, Peru, during most months of the year (B. Walker *in litt.*, 2005), and the species has been recorded in all months at CICRA, although there is some indication that overall numbers may fluctuate seasonally (D.J. Lebbin *in litt.*, 2005; JAT). It is present year-round at Tambopata Research Center, but its abundance at the clay lick fluctuates seasonally (Brightsmith, 2004; Fig. 3).

Its occurrence at sites in lowland south-eastern Peru was described as "erratic" (Parker et al., 1991), and the notion that populations might undergo some form of nomadism has been repeated elsewhere (Collar, 1997). This would fit the pattern in large macaws and other psittacines in the region, which tend to vary in abundance and/or detectability throughout the year (Renton, 2002; DJB, unpubl. data). In addition, many Neotropical psittacines show large seasonal variations in local abundance and move long distances to track food across the landscape (Powell et al., 1999; Renton, 2001; Bjork, 2004). In conclusion, populations of Blue-headed Macaw probably fluctuate seasonally in density, but apparently do not withdraw completely from any section of their range. This means that range-wide extrapolations are not undermined by seasonal movements, but that impressions of rarity or abundance at any given site should be treated with caution until year-round data are available.

3.1.9. *Coverage*

We are aware of only three intensive ornithological surveys within the lowland range of the Blue-headed Macaw that produced no records of the species. Two of these were near the edge of the global range in Dpto. Pando, Bolivia: Blanca Flor (11°44′ S, 66°57′W) and San Sebastián (11°24′S, 69°01′ W; Alverson, 2003; Alverson et al., 2000). At the third site, near the heart of the range, Lloyd and Marín (2000) failed to find the species during five 18-day bird surveys at Eco Amazonia on the lower Río Madre de Dios (12°32′ S, 68°56′ W). However, this same study, with the same sampling effort, did not locate the species at Cusco Amazonico, a site for which we have four records of 2–10 individuals (R. Amable, pers. comm.). The fact that we can list so few failed surveys in the lowlands suggests that the huge gaps evident in the range map are sampling artefacts (Fig. 1), and that much of the global range of this species remains to be surveyed (T.S. Schulenberg *in litt.*, 2005).

In the Andean foothills (500–1500 m) records of this macaw are concentrated around sites with humid lower montane forest accessible by road: Marcapata valley, Cosñipata valley, Urubamba valley, and the regions of Satipo and Tingo Maria. Recent ornithological explorations along a remote road to the upper Río Tambopata, Dpto. Puno, Peru, have also encountered the Blue-headed Macaw (D. Geale *in litt.*, 2006). These localities are well spaced along the Andean chain, giving an impression of a localised distribution, but they coincide with the only access points to suitable habitat. Given this sampling constraint, the available evidence suggests that the species is distributed continuously along a 2000-km stretch of the Andes between Cordillera Azul National Park, Peru, and the Peru-Bolivia border (Fig. 1).

In conclusion, the lowland and upland ranges of the Blue-headed Macaw span large areas of remote, unexplored terrain, and the mapped localities in Fig. 1 approximate to a scatterplot of ornithological coverage.

3.1.10. *Population size*

Summing minimum population data at each locality gives an estimated minimum global population of 545 individuals. However, this is an underestimate because: (1) repeated sightings at the same locality are likely to involve different birds; (2) many sightings are never reported; (3) the areas visited by experts make up a tiny proportion of the total range. The more widely accepted method of estimating populations of species that are too abundant and widespread to census directly involves the extrapolation of population size from density and area estimates (Bibby et al., 2000).

To assess previously published population estimates we can work backwards to determine what densities they represent. BirdLife International (2007a) estimated a maximum population size of 2499 mature individuals and a range size of 373,000 km^2. This suggests a mean population density of one mature individual per c.150 km^2. Applying this published population size to our own EOO estimate (460,000 km^2) produces a mean density of one mature individual per 184 km^2. These estimates are obviously too low given that multiple individuals have been reported at most sites, and flocks of 50–60 individuals at two sites (see *Flocking behaviour*). Even using the earlier global population estimate of 10,000 (Lambert et al., 1993), the mean density is one individual per 46 km^2. This is more realistic, but also seems too low.

Unfortunately, there are no systematic density estimates of Blue-headed Macaws at any site. Point count and plot data have failed to produce useable density estimates at Cocha Cashu (Terborgh et al., 1990) and Tambopata (Lloyd, 2004) because the methods only detected densities higher than 1 individual per 2–4 ha. The best quantitative data come from systematic counts at five observation points in Peru, where the species was encountered at an average rate of once every 2–10 h (Table 2). Another useful data set was collected in the Camisea region of the Río Urubamba, Peru, where T. Valqui (*in litt.*, 2006) surveyed parrots in 2004 using 20-species lists (Mackinnon and Phillipps, 1993; Poulsen et al., 1997; Herzog et al., 2002); the Blue-headed Macaw was recorded in 24% of 210 such lists (T. Valqui *in litt.*, 2006). Only three other parrot species were detected more often (*Pionus menstruus* (34%), *Ara ararauna* (30%) and *Amazona farinosa* (27%)), and many common species were recorded less regularly (e.g. *Aratinga weddellii* (15%), *Ara severus* (6%), *Brotogeris cyanoptera* (6%)).

These data tell us little about population density, except that it is undoubtedly far higher than one adult per 184 km^2, and presumably higher than one adult per 40 km^2. This seems especially likely given that a closely related species of comparable size and ecological requirements, *Primolius maracana*, occurs at densities of up to four individuals per 1 km^2 (Evans et al., 2005). Most of our 61 localities are easily accessible by road or river (see Supplementary data), suggesting a bias towards areas affected by trapping, which may potentially underestimate abundance. If we make a conservative estimate of one mature Blue-headed Macaw per 10–50 km^2 and an EOO of 460,000 km^2 we arrive at a tentative global population estimate of 9200–46,000 mature individuals (11,500–57,500 individuals if immature birds are included, in accordance with our estimation of a 4:1 ratio).

It might be argued that we should extrapolate population density to an estimated area of occupancy (AOO), the area within the EOO which is occupied by a taxon, excluding cases of vagrancy (IUCN, 2001). However, this definition is subject to problems of scale, because finer-scale analyses are more likely to detect gaps in distribution. To control for this, AOO is generally measured by a standardised procedure (the sum of 2×2 km grid squares known to be occupied). Unfortunately, data of this type are lacking for the Blue-headed Macaw, and most other tropical species. Our estimates of range size and population size are therefore derived from the relatively coarse-scale EOO approach, a method which is sometimes questioned on the grounds that many species are mobile or patchily distributed. While these factors are unavoidable sources of error, we argue that the Blue-headed Macaw is unusually amenable to EOO extrapolations because we have shown that it occurs at $\geqslant$95% of surveyed sites, uses a variety of forest types, and inhabits a range that remains $\geqslant$90% forested.

3.1.11. *Population trend*

Habitat destruction and trapping have resulted in declining populations for some Amazonian psittacids (Karubian et al., 2005), but we cannot discount the possibility that the Blue-headed Macaw is increasing with the spread of degraded forests along rivers. We find no evidence from sightings data of a decline in range or numbers in the wild population, and long-

Table 2 – Encounter rates for Blue-headed Macaws during systematic surveys in south-eastern Peru

Locality	Type	Date range		Hours	Individuals per hour	Groups per hour	Source
Posada Amazonas	Tower observation	1 December 2001	9 March 2002	83	0.45	0.16	DJB unpubl. data
Tambopata RC	Forest point count	1 January 2003	31 December 2005	521	–	0.07	DJB unpubl. data
Las Piedras	Overlook observation	1 June 2005	6 July 05	64.5	0.29	0.11	A. Lee unpubl. data
CREES	Clearing observation	26 January 2006	9 February 2006	45	0.87	0.47	E. Tavera unpubl. data
CICRA	Clearing observation	11 August 2006	18 September 2006	85	1.1	0.56	JAT unpubl. data

Survey sites include Posada Amazonas Lodge on the Lower Río Tambopata, Tambopata Research Center on the Upper Río Tambopata (13°08′S, 69°36′W), Las Piedras Biological Station, CREES, the Rainforest Education and Resource Center (12°45′S, 71°14′W), and CICRA. Coordinates are given for sites not mapped in Fig. 1. No estimates of numbers are given for forest point counts as most groups were heard only.

term data reveal a recent increase at the clay lick near Tambopata Research Center, Peru (Fig. 3b; see Section 3.1.5.).

BirdLife International (2007a) inferred a population decline for the Blue-headed Macaw because (1) sightings in Bolivia were reported to have dwindled, with "few reports in the north (mainly Pando), but none in the last 8–9 years, despite a number of studies in the area", and (2) the number of birds traded locally and internationally was apparently increasing. These factors were causally linked in the suggestion that the species is "declining owing to unsustainable exploitation for the cagebird trade" (BirdLife International, 2007a). Our review of records (Supplementary data) shows that it has been encountered quite consistently in Bolivia after its discovery there in 1986, with records in 1989–1992 (2), 1997 (2), 2002, 2004, and 2005 (3). As for trapping pressure, it is possible that it is currently sustainable because the global population is fairly large, and much of the global range is remote and rarely visited by trappers. Thus, current trends remain highly uncertain. For the purposes of assessing conservation status we tentatively assume a decline on the basis of an apparent increase in trade (see Section 3.2.2).

3.2. Conservation

3.2.1. *Levels of protection and changes in forest cover*

The Blue-headed Macaw occurs in at least 10 major protected areas in Brazil (Serra do Divisor National Park), Bolivia (Madidi National Park and Reserva Nacional Amazónica Manuripi-Heath), and Peru (Cordillera Azul National Park, Manu National Park, the Alto Purús Communal Reserve and National Park, Los Amigos Conservation Concession, Tambopata National Reserve and Bahuaja Sonene National Park). These protected areas cover a combined area of 110,216.5 km^2, which constitutes 18.7% of the estimated global range size. This figure, though impressively high, is misleading because three national parks (Cordillera Azul, Manu and Madidi) contain a large area of unsuitable habitat.

In Peru and Bolivia, the most accessible Andean foothills are being rapidly degraded, but very large areas remain remote and untouched. In western Amazonia the proportion of forest cover is still high (Nepstad, 1999), although extensive patches of forest have been cleared around some major towns, and large areas in all range states have experienced, or are slated for, selective logging (we have no evidence that this activity removes habitat for the Blue-headed Macaw).

Forest loss is likely to escalate in future as regional development intensifies. In Brazil, the states of Rondônia and Acre are suffering from massive conversion to agriculture and cattle ranching. This type of clear-felling has hardly affected the neighbouring department of Pando, Bolivia, as can be seen by viewing recent aerial and satellite imagery (Flash-Earth, 2006), but there are plans to develop this region (A.B. Hennessey *in litt.*, 2004). Perhaps most alarmingly, a major new road project (the Transoceanica Highway) will connect the Brazilian State of Acre to the Peruvian coast, via Puerto Maldonado (Conover, 2003), bisecting the range of the Blue-headed Macaw. In Bolivia, another road is planned from Ixiamas to Puerto Heath (R. Wallace, pers. comm.), passing through a massive area of pristine forest and traversing part of Madidi National Park. Given the impact of roads elsewhere in Amazonia (Nepstad et al., 2001), these projects are likely to cause an increase in habitat loss, human settlement, and associated exploitation.

3.2.2. *Human exploitation*

There are no direct reports of hunters targeting Blue-headed Macaw but hunting of parrots in general is widespread. Local people, especially indigenous communities, are known to hunt macaws at clay licks for food and ornamental feathers (Burger and Gochfeld, 2003; M. Herrera *in litt.*, 2005). The severity of this threat to the Blue-headed Macaw is not known, but is probably small as feathers of this species have not been seen in local handicrafts and hunters seeking food usually target larger species of macaw (DJB).

Until recently the Blue-headed Macaw was considered rare in captivity (Collar, 1997; Juniper and Parr, 1998), but traffic is apparently increasing (CITES, 2002). Reported international trade was virtually unknown before 1995, but 150 birds (plus 50 reported to have been seized/traded illegally) were traded between 1993 and 2000 (BirdLife International, 2007a). Moreover, three traded birds in 1993 increased to 55 traded birds in 2000 (BirdLife International, 2007a). It is now thought to be highly sought-after in the avicultural community, with "an iconic status as a rarity" (N.J. Collar *in litt.*, to CITES, 2002). Recent prices of US$ 3500 in Peru and US$ 12,500 in Europe (CITES, 2002) are well above the threshold that normally prompts intensive trapping and nest-poaching in this region (Wright et al., 2001). On this basis "it can be assumed that trade will continue and even increase" (CITES, 2002).

There is very little information about trapping techniques and activity, but some trappers apparently focus on unprotected clay licks. Unspecified traps were used in 2003 at the Cachuela lick, Río Madre de Dios, Peru (A. Lee *in litt.*, 2007). This is attended by Blue-headed Macaws, but it is not known whether trappers targeted this species, nor whether trapping activity continues. In the mid-1990s, logging personnel and local communities reported that a team of professional, itinerant parrot trappers (apparently from Pucallpa) worked at more than one significant parrot/macaw clay lick on the lower Río Urubamba, near Atalaya, Peru (C. Munn *in litt.*, 2007). It seems likely that they were trapping Blue-headed Macaw, a regular visitor to clay licks in this area, but it is not clear whether they were successful. This threat has apparently been reduced by conservation organizations working with local people to protect the clay licks (C. Munn *in litt.*, 2007). The situation in remote parts of Amazonian Peru, Brazil and Bolivia is not known.

Foreign traders are thought to purchase the Blue-headed Macaw in and around towns in Peru, Brazil and Bolivia, with an unverified report of "hundreds" passing through some markets in Brazil (CITES, 2002). As yet there is little control of this activity, although c.30 individuals have been confiscated by the Peruvian Government (INRENA) and are currently housed in zoos in Lima (A. Cácares *in litt.*, 2006). Traded birds are destined for a variety of countries; some have been confiscated in Mexico and Eastern Europe, and at least 50 were smuggled from Russia to the Czech Republic in the 1990s (CITES, 2002). Investigations of illegally held birds in Germany resulted in approximately 30 specimens being seized in 2001 (CITES, 2002).

3.2.3. Captive breeding programmes

The avicultural community plans to "establish a breeding programme for conservation purposes" (CITES, 2002). An international cooperative breeding program has been established and is being overseen by the American Federation of Aviculture; there are no plans to re-introduce birds from captivity, but 35 + individuals at Loro Parque might be viewed as an insurance against future need if new bloodlines can be added to this population (D. Waugh *in litt.*, 2006). There are also c.30 birds in zoos and breeding centres in Lima, Peru (A. Cácares *in litt.*, 2006). We suggest that no additional individuals be taken from the wild, but efforts should be made to bring together birds already in captivity in accredited institutions and breeding consortia. Towards this end, governments and international institutions should encourage collaboration and exchange of individuals among established programs.

3.2.4. Applying Red List criteria

The Blue-headed Macaw is listed as Endangered under criterion C2a(i) of the IUCN Red List (BirdLife International, 2007a), and it is therefore "considered to be facing a very high risk of extinction in the wild" (IUCN, 2001). Conversely, we argue that it faces a very low risk of extinction, even in the long-term. To qualify for the Endangered category under criterion C2a(i) a species has to have a declining global population of <2500 mature individuals, with "no subpopulation estimated to contain more than 250 mature individuals" (IUCN, 2001). BirdLife International (2007a) stated that the species lives in >1 subpopulation, the largest of which contains 50–249 birds. We deal with each of these parameters in turn.

First, the evidence for a decline is weak and largely inferred from trade reports (see Section 3.1.11 *Population trend*). Second, the population structure given by BirdLife International (2007a) is inaccurate. All Blue-headed Macaws probably belong to a single population given that lowland and foothill populations are apparently contiguous and western Amazonian forests are not yet fragmented into blocks. The mobility of macaws, and their ability to disperse over broad rivers and open areas, is illustrated by the high genetic similarity of Blue-and-yellow Macaws *Ara ararauna* collected over 2000 km apart in Amazonia (Caparroz, 2003). This implies that the Blue-headed Macaw does not meet subcriterion C2a(i). Third, our field data suggest that the estimated population size of <2500 mature individuals is unduly pessimistic. Although we can account for a minimum number of 545 individuals, a conservative extrapolation across the available habitat produces a higher population estimate (9200–46,000 mature individuals). This exceeds the threshold for Endangered under criterion C (2500 mature individuals), but – applying the precautionary principle – it falls below the threshold for Vulnerable (10,000 mature individuals). We therefore recommend that the species be reclassified as Vulnerable under criterion C2a(ii), on the grounds that the population may contain fewer than 10,000 mature individuals, "at least 95% of which occur in one subpopulation" (IUCN, 2001), and may be undergoing a continuing decline.

3.2.5. Data quality, data deficiency, and the Red List process

Previous status assessments for the Blue-headed Macaw were made with the caveat that data quality was poor (BirdLife International, 2007a). Indeed, it may have been more realistic to classify this species as data deficient (DD), were it not for current policy regarding this category. IUCN (2001) state that DD should only be assigned "where data are so uncertain that any category is plausible", and also that "the absence of high-quality data should not deter attempts at applying the [Red List] criteria, as methods involving estimation, inference and projection are acceptable so long as these can reasonably be supported". These recommendations permit a degree of subjectivity, despite careful wording. How certain must data be before a category is plausible? And what data are required before support is deemed reasonable? For the Blue-headed Macaw the answer was one expert opinion, 10 localities and four reliable sources of information (Gilardi, 2003). This data set gave rise to a smaller population estimate, and a higher category of threat, than was produced by more rigorous analysis. Although the IUCN (2001) stance on inferential assessments is necessary given the constraints of funding and time, it effectively encourages "Red List Authorities" to make status assessments on the basis of limited data sets. This policy can exaggerate the estimated extinction risk of poorly known species, as illustrated by the Blue-headed Macaw.

As they focus on a single species, our results are not broadly representative. However, many threatened species occur in the tropics, or in remote regions, where relevant information (population size, range size, demography and trends, etc.) is often based on inadequate data (see e.g. McGowan et al., 1998; van Balen et al., 2000). Species may also be data-poor simply because they are difficult to detect (Pimenta et al., 2005; Broderick et al., 2006; Hill et al., 2007). Poor data may influence estimates of population size, range size and rates of population decline; moreover, poor data are not restricted to recent shifts in status, or to species not covered by high-quality, in-depth reviews (e.g. Collar et al., 1992, 2001). Thus, it seems likely that a significant proportion of species classified as threatened, if subjected to detailed field work and analysis, would be shown to be more widespread or numerous than suspected on the basis of limited data (e.g. Jones et al., 1995; Tobias and Seddon, 2002; Seddon and Tobias, 2007; Tobias et al., in press; Trainor, in press).

This paper adds to a growing number of studies suggesting that poor data can create bias in Red List classifications. In particular, variations in sampling effort and data depth may influence conservation status assessments in data-poor scenarios: extra field surveys and research efforts tend to unearth new records and localities, and these in turn tend to increase range size and population size estimates. Further field work in the range of the Blue-headed Macaw will extend this process, perhaps resulting in a downlisting of the species to Near Threatened or Least Concern, depending on rates of trade and habitat loss. However, comprehensive fieldwork is not possible in this case because, as with many other tropical species, much of the range is difficult, costly or dangerous to visit.

Our results highlight the importance of extensive field surveys, grey literature and expert knowledge in building a clear picture of the distribution and status of poorly known threatened species. This task, traditionally the responsibility of Red List Authorities, is becoming ever more challenging with the increase of published and unpublished information. The trend is reflected in our data sources (Supplementary data), and the recent proliferation of biodiversity-related articles and reports. In one department (Madre de Dios) in south-eastern Peru, the publication rate has increased from fewer than 10 texts/year in 1970 to nearly three texts/week in 2004 (Pitman et al., 2006). These figures do not include a growing number of outputs made available on the internet.

Although the immense value of the Red List to conservation is beyond doubt (Collar, 1996; Butchart et al., 2004; Rodrigues et al., 2006), Red List data should be used cautiously in scientific analyses and priority-setting exercises (Possingham et al., 2002). The broad nature of Red List categories deals to some extent with bias and uncertainty (Butchart et al., 2004), but not to the scale associated with many tropical species, including the Blue-headed Macaw. Previous proposals for dealing with these issues include making Red List categories fuzzy (Regan et al., 2000), assigning more than one category per species (Akçakaya et al., 2000), or broadening the DD category to capture more poorly known species (Mrosovsky, 1997). These modifications have not been widely adopted, either because they destabilize the Red List process, or because they take too much time. A simpler method for dealing with uncertainty is to remove from analysis all assessments based on poor quality data, at least to test the effect of data quality on results (see e.g. Butchart et al., 2004).

4. Conclusions and recommendations

The Blue-headed Macaw is vulnerable to overexploitation because of its relatively small geographic range and high market value. However, there is no immediate need to initiate intensive *in situ* or *ex situ* management. The most urgent priority is the investigation and control of illegal trade, in line with the regulations stipulated for Appendix I of CITES. Trading activity should be monitored through customs data, as well as systematic surveys at key markets. Field work and local knowledge interviews should seek to determine the prevalence of hunting and trapping at clay licks, and where necessary the protection of clay licks should be expanded. Studies of habitat preferences, breeding requirements and seasonal movements are needed, as are frameworks for measuring and monitoring population density and trends at key sites, with an emphasis on year-round or multiple-season studies rather than rapid assessment surveys. In the long-term, the future of the species relies heavily on effective protection of parks, reserves and concessions in Amazonian Peru, northern Bolivia and western Brazil.

In a broader sense, our results underscore the importance of feeding high quality data into the Red List process. In birds, the best known class of organisms, 40% of threatened species are listed on the basis of "poor" quality data (Butchart et al., 2004). We recommend that data quality is assessed for all taxa, in line with definitions proposed by BirdLife International (2007b), and that funding agencies support baseline field surveys and Red List status reviews for species listed as data-poor.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2007.06.009.

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