The dichotomy between protection and logging of the Endangered and valuable timber species *Amburana cearensis* in north-west Argentina

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Abstract *Amburana cearensis* is a commercially valuable timber species, categorized as Endangered on the IUCN Red List. It is distributed throughout the seasonal dry tropical forests of Brazil, Paraguay, Bolivia, Peru and Argentina. In Argentina it is restricted to the provinces of Salta, where legislation sets a minimum cutting diameter of 60 cm, and Jujuy, where logging of this species has been banned since 1972. The effect of these laws on the species' conservation status has not been assessed. We estimated species density, using distance sampling methodology, and measured the diameter at breast height of each individual encountered at 13 sites in north-west Argentina. Across both provinces we found a density of 1.12 individuals ha^{-1} (95% CI 0.48–2.63) and there was no significant difference between the density in Salta (5.15 ha^{-1}; 95% CI 3.14–8.45) and that in Jujuy (3.67 ha^{-1}; 95% CI 2.59–5.17), although 84% of the individuals encountered in Salta were found at one site. Diameter at breast height was significantly lower in Salta than in Jujuy (23 ± 12 vs 41 ± 18 cm; P < 0.05). These differences in the demography of the species between the provinces may be attributable to the application of different legislation. Our results indicate that it would be prudent to halt logging of this species in Salta until further information is gathered and a sustainable management plan developed.

Keywords *Amburana cearensis*, CITES, conservation status, density, IUCN Red List, minimum cutting diameter, population structure, sustainable forest management

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Introduction

The lack of scientific information on the ecology and biology of valuable tropical tree species impairs the development of adequate legislation and management guidelines for ecologically sustainable forestry (Mostacedo & Rumiz, 2010). A common argument for continuing to log tropical forests is that if native forests do not provide an economic alternative they are more likely to be cleared for agriculture or plantations (Merry et al., 2009). Such arguments are based on the assumption that appropriate laws and regulations guide management (Shearman et al., 2012). However, enacting legislation does not improve forest management unless the laws are enforced. This is a problem given that it is estimated that 40% of the world's tree species are threatened with extinction (Oldfield et al., 1998; Newton & Oldfield, 2008). Therefore assessment of the conservation status of threatened tree species is a priority for designing appropriate conservation plans and policies (López-Toledo et al., 2011), particularly as the portion of natural tropical forest area under timber production has increased steadily over time (Guariguata et al., 2012). Despite the increase in sustainable forest management plans throughout the tropics (ITTO, 1990; Poore & Sayer, 1991) an estimated 127,300 km^2 of tropical forest is lost annually (FAO, 1999). Over 90% of tropical forests are managed unsustainably (Blaser et al., 2011) and only a small percentage of the total area of tropical forest is under certified sustainable management (Bowles et al., 1998).

Amburana cearensis (Fr. Allem.) A.C. Smith (South American oak, known locally as *roble*) is a Neotropical tree species of the family Fabaceae, subfamily Papilionoidea, with a geographical range covering the seasonal dry tropical forests and transition zones of Brazil, Paraguay, Bolivia, Peru and Argentina (Dimitri, 1997). This region constitutes a phytogeographical entity: Seasonally Dry Tropical Forests of the Pleistocenic Arc (Prado, 2000). Although *A. cearensis* has high economic value and is categorized as Endangered on the IUCN Red List there has been no effort to delineate a conservation and management plan for the species (Leite, 2005; Americas Regional Workshop, 1998). The species' distribution, population structure and regeneration pattern are poorly documented, making it difficult to develop management guidelines (Osinaga Eguez, 1997). *A. cearensis* attains large dimensions: 15–25 m height and 40–110 cm diameter at breast height (DBH; López et al., 1987) and has

a moderate growth rate (0.89 cm year^{-1} in diameter), although initial growth is slow (Calzon & Palma, 2008). It starts reproducing when DBH reaches > 60 cm; 90% of individuals attain reproductive age when they reach DBH > 67 cm (van Rheenen, 2005; Ayarde, 2006). The species bears seeds every 3–4 years, during September–October (Ayarde, 2006). Ripe seeds are dispersed from the open legume and lose viability quickly (López et al., 1987).

In Argentina *A. cearensis* is restricted to the provinces of Salta and Jujuy, in a narrow belt (400–750 m altitude) of the Sub-Andean Piedmont Forest (Prado, 2000). This forest harbours a high number of species (e.g. 300 woody species, of which 113 are trees, 39 amphibians, 137 birds, and 106 mammals) and is the most threatened forest ecosystem of Argentina (Brown et al., 2006). Analysis indicates that the remaining area of piedmont forest is $< 37\%$ of its original cover, and most of the remaining stands are confined to steep and less accessible areas (Brown et al., 2009). The remaining piedmont forests are degraded and almost all stands have been affected by logging (Brown et al., 2002), in which harvesting is focused on a few valuable timber species, with virtually no inventory or planning. Forestry statistics show a decreasing trend overall in timber volume of all species harvested and a concomitant increase in the area logged, probably associated with a depleted timber stock (Eliano et al., 2009).

Unplanned and extractive logging in the piedmont forest has compromised most valuable timber species, including *A. cearensis*. In the province of Salta the decrease in the number of individuals of *A. cearensis* prompted a 1960 decree (No. 15.742/1960) restricting logging to individuals of > 60 cm DBH (minimum legal cutting diameter). In Jujuy province logging of the species was banned in 1972 (Decree No. 676-H-72). The mismatch between legislation in these neighbouring provinces and the lack of control has made law enforcement difficult. Furthermore, forest management plans do not prioritize the protection of this valuable resource. For these reasons information about the status of this species is needed. We analysed the size and structure of the population of *A. cearensis* in the two provinces, to assess whether different legislation has influenced the conservation status of the species.

Study area

The study was conducted in the Sub-Andean Piedmont Forest of the Upper Bermejo River in north-west Argentina (Fig. 1). The forest covers c. 900,000 ha (80% steep terrain and 20% flat terrain; Brown et al., 2009). Annual rainfall is variable (800–1,000 mm), with a pronounced dry season during March–November; Bianchi et al., 2008). Mean annual temperature is 18–20 °C, with peaks of > 40 °C in the summer (Bianchi et al., 2008). Mature piedmont forest stands in north-west Argentina have a continuous canopy

25–35 m in height, a basal area of 25–30 m^2 ha^{-1} and c. 35–40 tree species ha^{-1} (Brown & Malizia, 2004). They also have thorny shrubs and a number of xerophytic elements (Prado, 1995).

Methods

We surveyed, using distance sampling (Buckland et al., 2001), at 13 sites (five in Jujuy and eight in Salta; Table 1; Fig. 1) in areas where the species could be present based on its potential distribution in north-west Argentina, an area of 1,732 km^2 (Malizia et al., 2009). Distance sampling methodology is more appropriate than conventional sampling methods for estimating the density of rare species that are sparsely distributed across large geographical areas (Cochran, 1977; Buckland et al., 2001). From May 2007 to May 2008 we established 20 100 m transects of variable width at each site to detect individuals of *A. cearensis*. Its characteristic bark makes the species particularly easy to detect. When an *A. cearensis* tree was detected we measured the perpendicular distance from the transect line to the tree, using a metric tape. The DBH of each individual was measured 1.3 m above ground, using a metric tape. We conducted a more detailed survey from October 2010 to October 2011, covering 70 ha at Finca Río Seco (in Salta province), owned by the forestry company Forestal Santa Bárbara, and 72 ha at Finca Yuchán (in Jujuy province), owned by the agribusiness firm Ledesma. To our knowledge these stands represent the best piedmont forest in north-west Argentina.

We used *Distance v. 5.0* (Thomas et al., 2006) for data analysis at two levels: province (Jujuy and Salta) and country (i.e. both provinces together). For each province we estimated density in three diameter size classes. Detection functions were selected based on Akaike's information criterion (Burnham & Anderson, 1998), χ^2 model fit statics and visual inspection of detection probability and probability density plots (Buckland et al., 2001). Grouped cut points and truncation distances were used to remove outliers from the analysis.

Results

A total of 813 individuals of *A. cearensis* were detected in 1,114 ha of the area surveyed in both provinces, yielding an estimated density of 1.12 ha^{-1} (95% CI 0.48–2.63). There was no significant difference between the density of the species in Salta (5.15 ha^{-1}; 95% CI 3.14–8.45) and that in Jujuy (3.67 ha^{-1}; 95% CI 2.59–5.17) although DBH was significantly lower in Salta ($23 \pm SD\ 12$ vs $41 \pm SD\ 18$ cm; $P < 0.05$). Density estimates decreased consistently with increasing DBH class, approximating a reverse J-shape (Fig. 2). The density of stems in the 5–20 cm DBH class was greater in Salta than in Jujuy and the density of stems in the > 40 cm DBH class was lower

TABLE 1 Details of sites surveyed for *Amburana cearensis* in the provinces of Jujuy (where harvesting is banned) and Salta (where harvesting is permitted), Argentina (Fig. 1) during 2007–2008.

Site	Altitude (m)	Area surveyed (ha)	Management[1]
Jujuy province			
Fraile Pintado	700	82	CTL
Rio Colorado	588	85	CTL
Finca Yuchán	663	96	NL
Calilegua National Park	519	198	NL
Calilegua National Park Northern Sector	710	75	NL
Salta province			
Pintascayo	699	74	FSC
Piquirenda	607	34	CTL
Acambuco Provincial Reserve and Buffer Zone	862	98	CTL
Río Seco (Finca Flores)	568	73	CTL
Embarcación	312	54	CTL
Finca Río Seco (Forestal Santa Bárbara)[2]	535	82	FSC
Surroundings of Tabacal	393	96	CTL
Valle Morado	442	67	CTL

[1]CTL, conventional timber logging; FSC, Forest Stewardship Council certification; NL, no logging since 1979
[2]Harvesting banned by the Forest Stewardship Council in 2008, pending the development of a management plan for the species
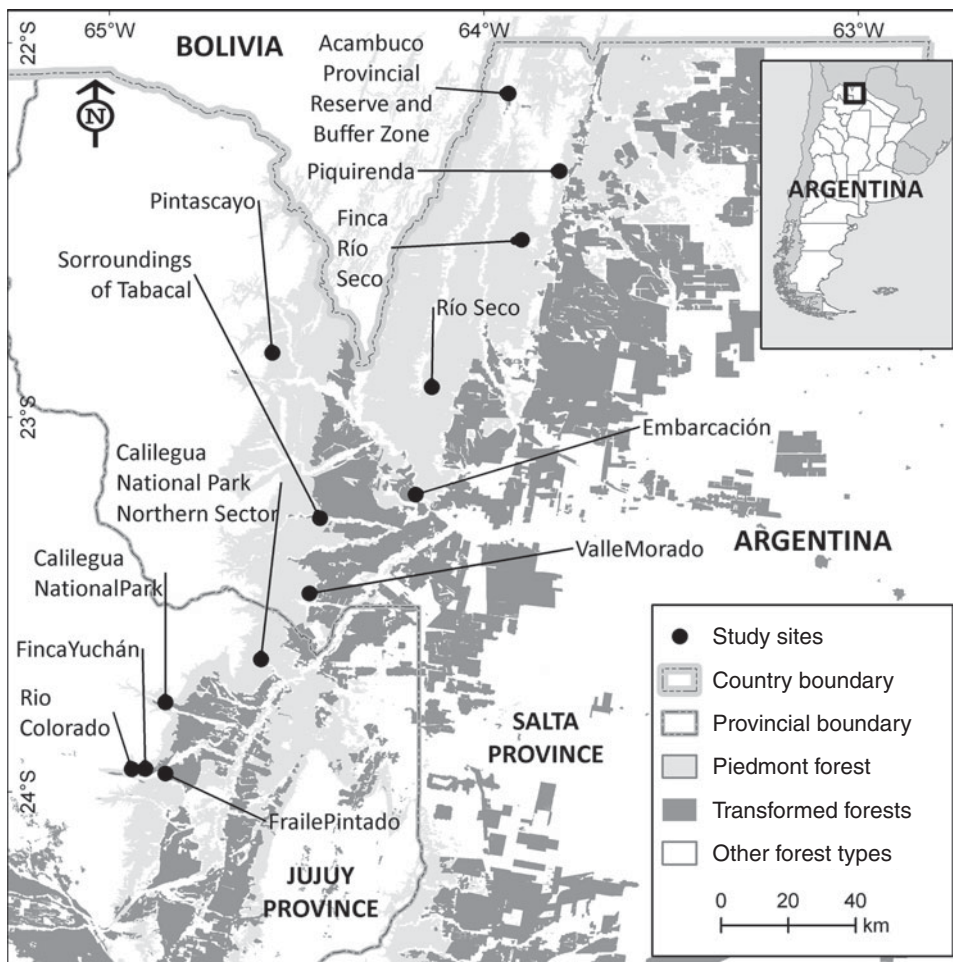

FIG. 1 Location of study sites (Table 1) in the piedmont forest of north-west Argentina. The rectangle on the inset indicates the location of the main map in Argentina.
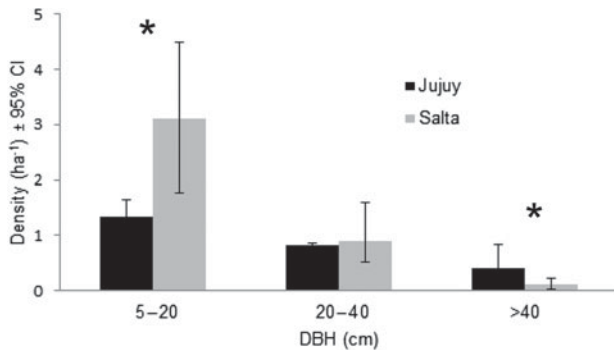
FIG. 2 Density (with 95% CI) estimates for *Amburana cearensis*, using distance sampling methodology based on diameter class distribution, in Jujuy and Salta provinces in Argentina (Fig. 1). An asterisk (*) indicates significant differences between provinces for a given diameter class.
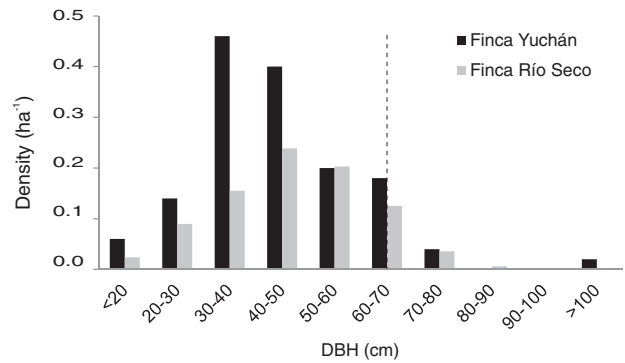

FIG. 4 Density of *A. cearensis* detected in Yuchán, Jujuy province and Finca Río Seco, Salta province, according to the diameter size class distribution. The dashed line indicates the legal cutting limit in Salta.
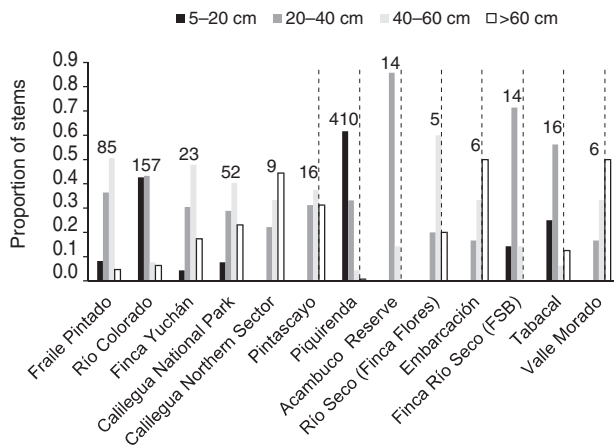

FIG. 3 Proportion of individuals of *A. cearensis* detected in each diameter size class (5–20; 20–40; 40–60; > 60 cm DBH) at each site surveyed. The dashed line indicates the legal cutting limit in Salta. The numbers above the bars indicate the number of individuals detected at each site.

in Salta than in Jujuy (Fig. 2). Most individuals (84%) encountered in Salta were found at one site (Piquirenda), which had a high proportion of individuals in the lower diameter classes (Fig. 3). Most sites (60%) had a bell-shaped distribution of diameter class (Fig. 3). The detailed diameter-class distribution in Finca Yuchán and Finca Río Seco also showed a bell-shape (Fig. 4). The density of the species was 1.5 ha^{-1} in Finca Yuchán and 0.4 ha^{-1} Finca Río Seco; there was no significant difference in DBH at the two sites (44.23 ± 17.49 cm vs 47.02 ± 14.17 cm; P = 0.20).

Discussion

Our data show differences in the characteristics of the populations of *A. cearensis* in the two provinces that may be attributable to the application of different legislation.

Nevertheless, although legislation in Jujuy has probably prevented further decline of the species there, it has not been accompanied by incentives to encourage research on the species. Conventional unsustainable timber management in Salta province appears to be having a negative effect on the population structure (there is a low density of individuals > 60 cm DBH). Sustainable use and trade in timber have been proposed as an economic incentive for forest conservation (Putz et al., 2001; Pearce et al., 2003; Newton, 2008) but the conservation-through-use argument requires that technical uncertainties, including lack of appropriate ecological information, are overcome (Dickinson et al., 1996; Newton, 2008). For example, to make appropriate decisions regarding effective silvicultural treatments for *A. cearensis* the reproductive biology of the species (Leite, 2005) must be understood. If logging continues in Salta province the species will probably decline further, leading to its economic extinction in this part of Argentina.

A. cearensis was categorized as Endangered on the IUCN Red List in 1998 but its status requires updating (IUCN, 2013). To identify regional bias as a result of population differences it is necessary to conduct national categorizations and integrate those regional assessments to determine the species' current status globally (Gárdenfors et al., 2001). Our results suggest that the categorization as Endangered is correct for Argentina, where the species has a low density. Previous stand-scale forest inventory surveys in Argentina also reported that *A. cearensis* has a low density (Ayarde, 2006; Malizia et al., 2009) and it was assumed that the species was rare historically (Calzón & Palma, 2008). The species is threatened by deforestation of the piedmont forest of north-west Argentina for agricultural and urban development (Eliano et al., 2010). Superimposed on this threat is the high logging pressure (Quiroga & Salinas, 1996), which decreases the density of the species, impairs its natural regeneration and could lead to local extinction (Fredericksen & Putz, 2003). In our study the low

proportion of stems that occur in the > 60 cm DBH class (i.e. the class at which the species starts reproducing) in Salta is an indication of the logging pressure on the species. The populations of *A. cearensis* in Finca Yuchán and Finca Río Seco were dominated by individuals of the intermediate size classes, with few individuals in the small and mature size classes. A similar bell-shaped distribution has also been reported from studies of *A. cearensis* in Bolivia, where most individuals were concentrated in the 30–50 cm DBH class (Osinaga Eguez, 1997). However, the Finca Yuchán population structure was skewed more to the left and had higher density in all diameter size classes compared to Finca Río Seco, which may indicate that the ban on harvesting in Jujuy has reduced pressure on the *A. cearensis* population in Finca Yuchán.

Conservation management must encompass social, economic and political trade-offs to reach practical solutions (Newton, 2007). In the absence of reliable scientific information on which to base management decisions it is wise to employ multiple strategies. We make the following recommendations for the conservation of *A. cearensis* in Argentina. (1) Incorporate areas that contain the largest populations and best age structure (i.e. those with a broad range of diameter classes represented) into the regional protected area network. Finca Yuchán, Fraile Pintado, and Rio Colorado are priority areas for conservation because the largest populations, with the best age structure, are found here (only 1% of the piedmont forest is currently under any legal protection; Brown et al., 2002). (2) Reinforce the population to facilitate natural regeneration (Doucet et al., 2009); this will probably require using nursery-sourced seedlings and, in the absence of genetic research, it is essential to ensure that these seedlings come from local seed stocks. (3) Develop the support and cooperation of a broad array of stakeholders (governmental policy-makers, NGOs, landowners, local citizen representatives and scientists) for restoration, conservation planning and protection of the species. (4) Legislate to protect remnant individuals of the species during land conversion, to conserve the genetic diversity of the species (Hamrick et al., 1992; Manning et al., 2006).

Improved knowledge of the ecology of *A. cearensis* is required (Hutton & Leader-Williams, 2003) before logging can be allowed in Jujuy province or continued in Salta province. Stringent forest management standards, such as forest certification criteria, provide an opportunity to develop management and conservation plans for threatened species (SmartWood, 2005). This strategy is currently being followed by the Forestal Santa Bárbara forestry company, which adheres to the principles and criteria of the Forest Stewardship Council. This company halted logging of *A. cearensis* in 2008 and has promoted research to develop a species conservation action plan (Forestal Santa Bárbara, 2011). Listing *A. cearensis* in Appendix I of CITES could restrict its international trade but could also inhibit the emergence of sustainable management practices and result in conversion of *A. cearensis* habitat to agriculture because of a lack of economic alternatives (Turner et al., 2001). In contrast, listing *A. cearensis* in CITES Appendix II, accompanied by management guidelines based on knowledge of the species' ecology and high forest management standards, could help promote improved management for timber exploitation and international trade. For example, forest management guidelines for the species should include a minimum cutting diameter of 90 cm DBH and retain 70% of the individuals recorded in forest inventories to ensure stems of medium-size diameter classes as seed sources for future regeneration. In Argentina management standards can be framed and supported by the National Forest Conservation Law (26.331), which has established a fund to promote restoration of degraded stands and develop sustainable forest management.

We have provided evidence that the approach to logging established in Salta province is not ensuring the conservation of *A. cearensis*. It is imperative that the status of this species be assessed and appropriate legislation and management be enacted, based on the species' ecology and biology (Schulze et al., 2008). We have passed our recommendations to the relevant decision-makers but they have not adopted them in management plans and forestry regulations. Therefore, we have begun an outreach programme to promote stakeholder involvement to implement silvicultural procedures for sound forest management. We are also conducting further research to determine the reproductive ecology and establishment requirements of this threatened and valuable timber species to refine our silvicultural prescriptions.

Acknowledgements

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